A webcomic of romance, sarcasm, math, and language

xkcd
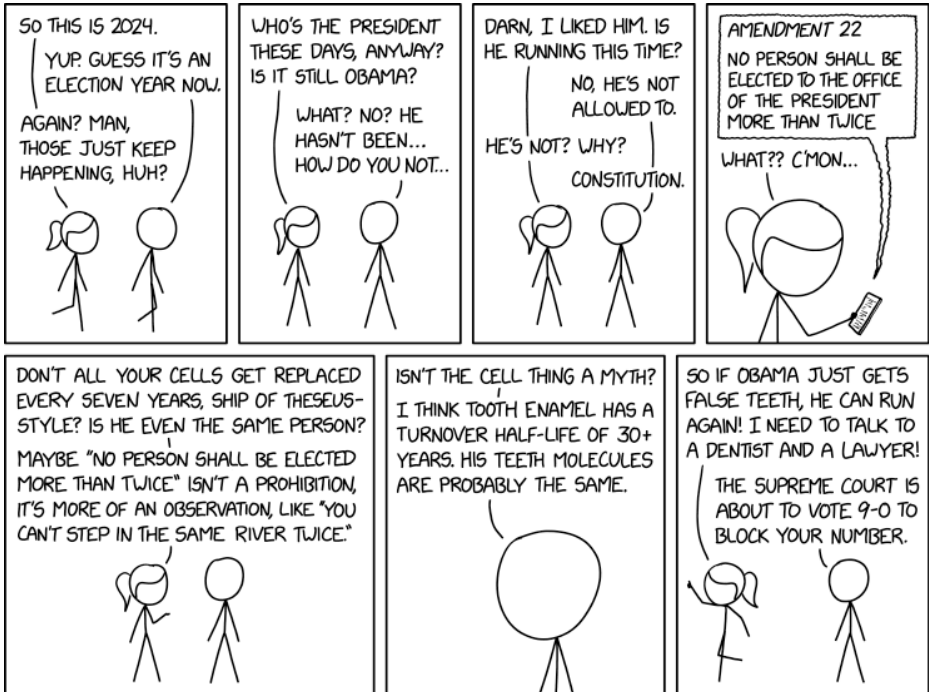
RANDALL MUNROE

2024

xkcd

2024

a collection of 157 webcomics

from #2875 to #3031

by Randall Munroe

#2875: 2024

January 01, 2024

It wasn't originally constitutionally required, but presidents who served two terms have traditionally followed George Washington's example and gotten false teeth.

Explanation

This New Year comic starts off almost like a "doesn't time fly?" scene, the unstoppable progression of the calendar is observed, as Ponytail points out that it's now 2024. This, though, is the only reference to New Year in the comic, and serves only as a pretext for Cueball to note that they are now in an election year, in this context a US Presidential election year, which occurs every four years and has (in one form or other) since 1788. Ponytail then replies in some form of exasperated tone that they "keep on happening", which is true but (normally) unsurprising.

On top of this, Ponytail seems to have not been aware of the passing of two whole election cycles as the discussion focuses upon Barack Obama, the President before Presidents Trump and Biden, who left office 7 (!) years ago, on January 20th, 2017. Ponytail states that she liked him, and wonders if he'll be up for taking on the position again. But Cueball states that he can't be made President again, having already served two terms, which Ponytail confirms by checking for herself the details of the Twenty-second Amendment to the United States Constitution.

In the second half of the comic Cueball and Ponytail discuss whether Obama is even the same person seven years after he was last president. Like the mythical Ship of Theseus, mentioned by Ponytail, which gradually had all of its parts replaced over many years, most of Obama's

constituent cells have been replaced since he was last president. Ponytail is thus looking into the possibility of Obama's re-election based upon philosophical/biological technicalities (as applied to the Constitution's words), rather than as legal/political convention might normally suggest.

Cueball questions if the cell replacement isn't a myth, and at least some cells may remain the same, especially those making up the enamel in the teeth, which he believes has a half-life of over 30 years, meaning that even after 30 years only half of the cells in your enamel have been replaced.

But even when Ponytail's approach is seen to be wanting, requiring a wait significantly exceeding 30 years, Ponytail suggests negating that issue by having all of Obama's teeth removed and replaced with false teeth.

In order to facilitate the latter goal, Ponytail announces her intention to consult both a dentist (presumably for getting the teeth replaced) and a lawyer (perhaps to establish that Obama could thus run for president again, hopefully in advance). Although, in Ponytail's frame of mind, it could also be to consult with the dentist to clear up the currently theoretical issues about tooth-biology, and the lawyer might be asked to serve an enforcement notice to force Obama to undergo the 'treatment'.

Seeing where her current misplaced, and less than informed, zeal might be leading her, Cueball appears to be about to suggest that the Supreme Court is about to

pre-emptively block her plan, but instead turns out, in a play on the word 'block', to be saying that they will be unanimous in blocking her phone number so that she cannot contact them again, suggesting that this just the latest in a string of ridiculous proposals she has attempted to bring before them, and they have finally lost patience. The Supreme Court being unanimous on any issue is now a comparatively rare event.

Although Cueball (and thus Randall) seems to think the suggestion has no merit, it is public knowledge that Randall did endorse Obama and in 1756: I'm With Her, he again showed that he prefers Democratic Presidents at least over Donald Trump. That he is not happy about Trump has been obvious in many comics (2220: Imagine Going Back in Time for an example), and Trump might be running for president again, in this election year, so it is not unlikely that Randall would wish that it was possible to get Obama back as president if in any way possible.
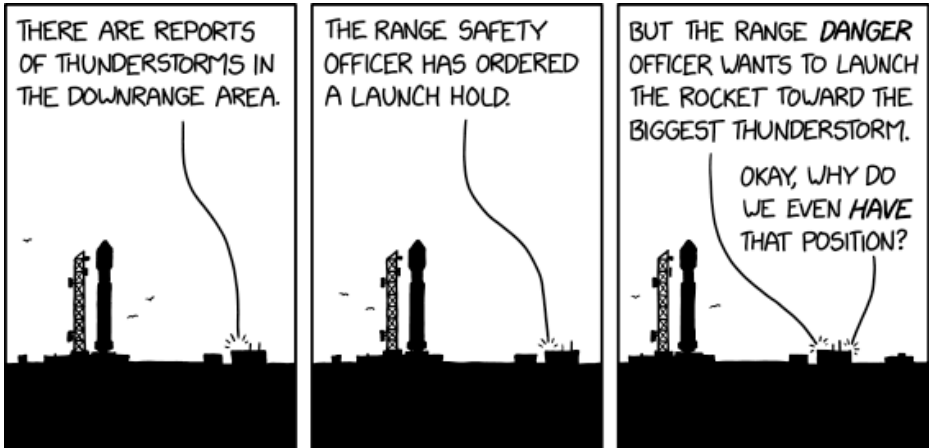
The title text combines two George Washington references. The first part of the sentence is the beginning of the mundane but true claim that "It wasn't originally constitutionally required, but presidents who have served two terms have traditionally followed George Washington's example and not sought a third term." However, the title text veers off-course to the subject of George Washington's (in)famous 'false teeth'. Washington's dentures are often falsely claimed to be made of wood; in truth they were real teeth procured from other sources. Regardless, this would have likely

resolved the rather specific philosophical/legal problems established in the comic, were they real. However, since Washington only ran for president twice, even if the 22nd amendment had been in effect, it would have been unnecessary!

It goes almost without saying that no one has yet even attempted to carry out this plan. Only one President has exceeded the 2-term limit; Franklin D. Roosevelt died in office during his fourth term, but he served prior to the 22nd Amendment and was thus unaffected by the rule, which was enacted six years after his death. (FDR did have a partial denture, but given that he retained some of his natural teeth, he did not engage in Ponytail's proposed scheme.) Presidents since then have definitely (and sometimes defiantly) tried various schemes aimed at securing a second term, with both successes and failures, but nobody has yet attempted this particular plan to achieve a third or beyond. Or at least one can assume that those that perhaps did (including, as noted, all those who were not yet 'required' to go to these lengths) failed to attain their goals for entirely different reasons.

#2876: Range Safety

January 03, 2024

Panel 1: THERE ARE REPORTS OF THUNDERSTORMS IN THE DOWNRANGE AREA.

Panel 2: THE RANGE SAFETY OFFICER HAS ORDERED A LAUNCH HOLD.

Panel 3: BUT THE RANGE *DANGER* OFFICER WANTS TO LAUNCH THE ROCKET TOWARD THE BIGGEST THUNDERSTORM.

OKAY, WHY DO WE EVEN *HAVE* THAT POSITION?

The Range Mischief Officer has modified the trajectory to add a single random spin somewhere in the flight, but won't tell us where.

Explanation

A Range Safety Officer is responsible for ensuring the safety of the flight of a missile or launch vehicle – such as the rocket in the comic. This involves tasks like creating a launch corridor clear of any aircraft or ships, as well as ensuring that atmospheric conditions are favorable for a launch. In this comic, the RSO has noticed reports of thunderstorms downrange, and has ordered a hold as conditions are no longer favorable. Randall continues on by imagining the opposite position, a "Range Danger Officer," responsible for ensuring that the flight of the vehicle is dangerous. Flying into the biggest thunderstorm may qualify as dangerous - in 1987 an ATLAS rocket launched into thunderstorm conditions by NASA was destroyed by lightning strikes that caused electrical malfunction. Finally, someone on the staff justifiably[citation needed] wonders what reason there is for that position to exist.

The title text additionally imagines a Range Mischief Officer, responsible for mischief – generally defined as minor/playful annoyance. Introducing a random unknown spin may qualify, since the spin shouldn't affect the flight too much, but would make all the flight engineers nervous about the flight as they seek to understand why telemetry is inverted (or why it is not!), as they work out the cause and whether it is symptomatic of bigger underlying issues or just a technical change of reference to an otherwise correct flight trajectory. Hopefully, the spin is just axial and not end-over-end, or

the rocket is having a bad problem and will not go to space today.

The "Range Danger Officer" is not an actual position at NASA or any other notable space agency. The Range Danger Officer and Range Mischief Officer titles both sound like suitable positions for Black Hat, xkcd's resident classhole. This is the second holiday season comic in 3 years to depict rocket safety officers. A Range Safety Officer was also mentioned in the title text of 2559: December 25th Launch, where the RSO shoots down Santa so he cannot interfere with the rocket launch.

#2877: Fever

January 05, 2024

TREATING A FEVER

FEVER	TREATMENT
38°C–40°C (100°F–104°F)	FLUIDS, REST, NORMAL DOCTOR STUFF
40°C–45°C	HOSPITAL, ADVANCED DOCTOR STUFF
45°C–100°C	EXIT THAT STEAM CLOUD IMMEDIATELY
100°C–400°C	STOP, DROP, AND ROLL
400°C–500°C	RETURN TO EARTH FROM VENUS ASAP
500°C–1,500°C	PLEASE CLIMB OUT OF THAT VOLCANO
1,500°C–5,000°C	TURN YOUR TUNNELING MACHINE AROUND AND COME BACK UP TO THE SURFACE
5,000°C–6,000°C	NO, THE SURFACE OF THE *EARTH*, NOT THE SUN
6,000°C–50,000°C	WAIT, THAT'S NOT THE SUN. WHAT STAR ARE YOU VISITING? COME BACK RIGHT NOW.
50,000°C–20,000,000°C	AT LEAST STAY ON THE *SURFACE* OF THE STAR INSTEAD OF DIVING DOWN TO THE CORE
20,000,000°C–10,000,000,000°C	YOU KNOW, YOU COULD'VE PICKED A NORMAL STAR INSTEAD OF ONE THAT'S EXPLODING
10,000,000,000°C OR HIGHER	I HOPE YOU'RE ENJOYING YOUR VISIT TO THE BIG BANG BUT YOU SHOULD REALLY COME BACK HOME IMMEDIATELY

Hypothermia of below 98.6 K should be treated by leaving the giant molecular cloud and moving to the vicinity of a star.

Explanation

This comic mimics charts on fever temperatures and actions that are indicated as a result. However, rather than dividing the normal body temperature range of a febrile (fever-having) patient into subtle grades, it quickly progresses beyond these to specify treatment for increasingly high temperature ranges, culminating with the most extreme temperature range ever achieved in the universe.

After the first two entries in the table, the rest refer to temperatures caused by the surrounding environment, rather than by conditions internal to the body (or the vapor/plasma cloud you would turn into if you reach this temperature...). Hence the 'treatments' consist of removing yourself from those environments.

Randall uses the SI related unit Celsius for all entries in the table, giving the temperature in Fahrenheit only for the first entry in the table about a normal fever temperature range.

The title text uses the real SI unit Kelvin, and suggests that those with temperatures under 98.6 Kelvin (-173.55 Celsius or -280.39 Fahrenheit) are in a molecular cloud and that they should get near a star to warm them up. 98.6 Fahrenheit (=37°C) is the average human resting body temperature, explaining why Randall chose this number, but 98.6 Kelvin is a good deal colder than this, and a temperature at which it would be very hard for a
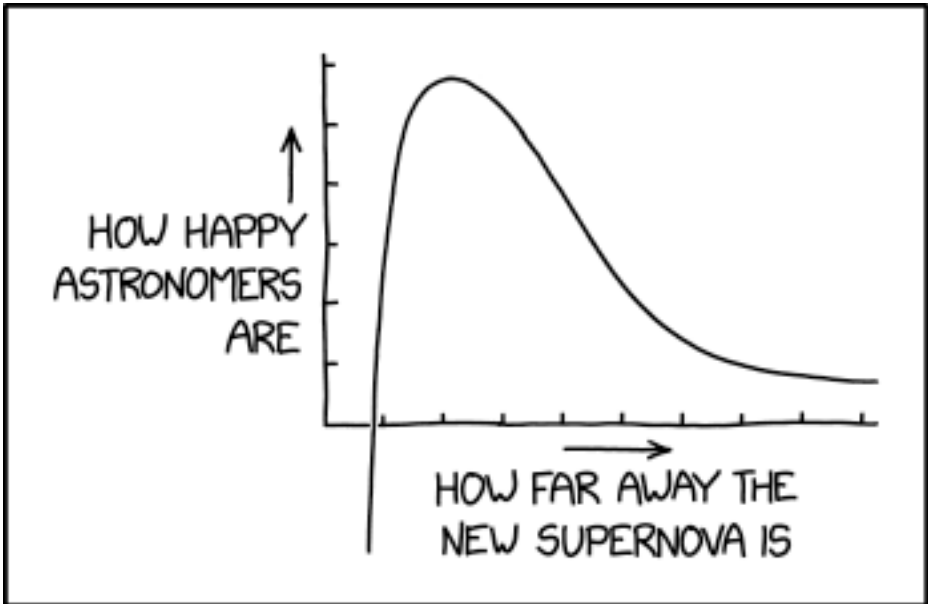
human to survive. By way of comparison, the normal boiling point of liquid oxygen is 90.19 K (−182.96 °C; −297.33 °F).

Taking an everyday situation to its logical extreme is a common humor trope, often used by xkcd.

Table of fever temperatures[edit]

HOW HAPPY ASTRONOMERS ARE

HOW FAR AWAY THE NEW SUPERNOVA IS

They're a little cagey about exactly where the crossover point lies relative to the likelihood of devastating effects on the planet.

Explanation

A supernova occurs when a heavy star can no longer produce enough energy to fight its own gravity, e.g. because its fuel runs out (type II) or because it has accreted too much mass from a binary companion (type Ia). The collapsing mass leads to a violent explosion, one of the most interesting events for astronomers to observe and one that can be used to glean information about the universe.

At first glance, the curved line on this graph might match that of the typical light curve of a type Ia supernova, constructed by plotting the brightness of the supernova as a function of time, with negative values indicating a logarithmic luminosity scale (below zero means a linear luminosity of less than the unit amount). In the event of a supernova, a star (which may previously have been unremarkable) becomes notably bright over a short period of time before trailing off again to leave a stellar remnant and expanding cloud of ejecta. Around the time of this comic's release new constraints on the expansion of the universe from the observation of type Ia supernovae were published, which used the regular shape of their light curves to establish a distance scale.

However, this comic reimagines the shape of a light curve graph to depict the relationship between the distance of supernovae from Earth, and the consequent happiness of astronomers, which happens to take a similar form. The further away the supernova occurs, the less detail can be

learned from it, so the graph beyond the maximum happiness distance appears to show an asymptotic approach to less and less astronomer happiness. On the other hand, a near-earth supernova close enough to flood the Earth with significant amounts of gamma and X-ray radiation might be considered too close. Its radiation could destroy life on Earth, or at least significantly harm the biosphere, which would be a bad thing.[citation needed] Astronomers (and many others) would be really unhappy if that happened, shown as a sharp drop in happiness towards smaller distances and negative happiness values for a supernova that is very close. In fact, if a supernova were to instantly destroy Earth, or kill off all life on it, astronomers may no longer be able to be happy or unhappy (depending on your theological/spiritual feelings), so distance values close to zero have undefined astronomer happiness values.

Many astronomers watch and study the stars in the night sky, even those that don't change appreciably over human timescales, but observing and recording such a huge event would be interesting for many reasons. Humans can observe some supernovae with the naked eye, especially if they occur within our own galaxy. A potential supernova in the news lately is Betelgeuse, a red giant star that is the left shoulder in the constellation Orion. About 430 light years from the Sun, it has been pulsating, dimming and brightening over exceedingly short time scales compared to the tens of millions of years such a big star is expected to burn. Betelgeuse should be far enough away from Earth that the inevitable explosion

would be safe enough for life on Earth (although some assessments are not so sure), but it will outshine all other stars in the night sky, competing with the Moon, and could even be visible during daytime. This would be a dream come true for many astronomers and something obvious to others interested in the night sky. In the first Stargazing comic, 1644, the wish that it goes supernova (in Randall's lifetime) is clearly expressed.

Since this should be safe for us, and since it would be a spectacle not seen at least since the start of recorded history, and unlikely to be seen again by human eyes, this would make astronomers very happy, not just from all they could learn, but also from all the increased interest in gazing at the sky with the 'new' star (and then seeing what happens to it next).

There are thought to be about three supernovae occurring per century within our own galaxy (most of which are much further away than Betelgeuse), and many other galaxies within which a supernova explosion can be detected. These remain useful to see, and are often studied as intensively as possible, but have decreasing amounts of thrill to them and are harder to notice/record in the early stages of the explosion (or immediately before, to add even more understanding).

The title text expands upon the point of "too close" supernovae, claiming that astronomers are not quite clear or perhaps unwilling to admit how close they would like a supernova to be. If it were close enough to severely impact the quality of human life, they would presumably

not be happy, but the title text suggests that they might actually be willing to accept some trouble on Earth if they get to see a supernova comparatively close by.

This is the second comic in a row that mentions exploding stars, after 2877: Fever, which like this comic is also a Charts comic.

#2879: Like This One

January 10, 2024
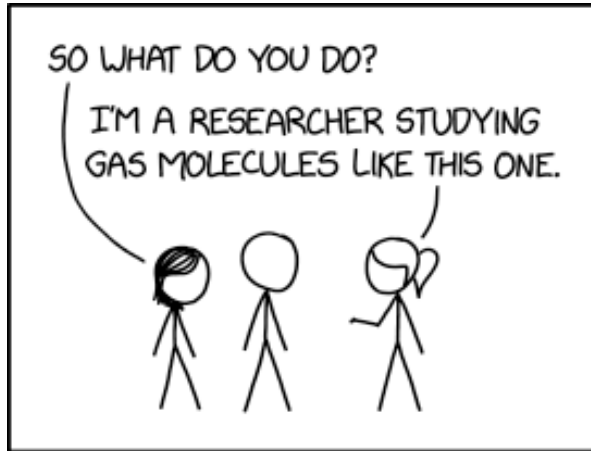
FIELDS OF RESEARCH WHERE YOU CAN ADD "...LIKE THIS ONE" AFTER YOU SAY WHAT YOU STUDY:

- GAS MOLECULES
- GRAVITATIONAL FIELDS
- PLANETARY MAGNETOSPHERES
- SOUND WAVES
- HABITABLE WORLDS
- LANGUAGES
- SOCIAL INTERACTIONS
- SKIN MICROBES

A lot of sentences undergo startling shifts in mood if you add 'like this one' to the end, but high on the list is 'I'm a neurologist studying dreams.'

Explanation

In this comic, Megan is asking Ponytail what she does, presumably in a professional context. Ponytail responds with "I'm a researcher studying gas molecules like this one" and then she indicates the air above her outstretched hand, or possibly pointing with a finger, which, indeed, does contain or point to gas molecules. However, it would not be at all clear which one molecule she was supposed to be identifying, since they are too small for human sight to distinguish. Identifying a specific gas molecule in this way does not provide the listener with any useful information.

The caption under the comic lists further examples of things that researchers study and are, by necessity, around them either all the time, or at any time they are talking to another person, making the researchers truthfully able to respond "...like this one" when asked about their research, despite the fact that such a statement doesn't tangibly identify anything to the other person.

- Gas molecules: Gas molecules generally share a few basic physical characteristics simply because they're in a gaseous state. A researcher would thus be able to make reference to their study of (any particular kinds of) gas molecules as, unless they happen to be researching something incredibly exotic, the gas molecules they were studying would probably share at least something with the gas molecules found in the atmosphere. A

more restrictive interpretation would be that the researcher is, in fact, studying particular kinds of gas molecules that are in the atmosphere.

- Gravitational fields: Every object with mass has a gravitational field that extends, however weakly, throughout the universe.

- Planetary magnetospheres: The Earth has a magnetic field, which covers the entire planet and any conversations taking place there.

- Sound waves: Most in-person conversations are mediated with sound waves created by human vocal cords, and those that are not (text or sign languages) are almost certainly in the presence of background noise.

- Habitable worlds: As of 2025, all humans converse on or near the habitable world of Earth.[citation needed] Depending on your definition of 'world', any environment in which a human could survive (and therefore hold a conversation) could be considered a 'habitable world'.

- Languages: Conversations such as this one are possible only if one or more languages are involved.

- Social interactions: Any conversation constitutes a social interaction.

- Skin microbes: For better or worse, a wide variety of microbial organisms live on the skin of any outstretched hand.

The title text moves into inverse cases, where it would be highly unusual or potentially disconcerting for an

example of the research subject to be present at the time of the conversation. In the example given, for a neurologist to say "I'm a neurologist studying dreams like this one", would imply that your conversation with them (or your entire consciousness) is itself a dream.

#2880: Sheet Bend

January 12, 2024
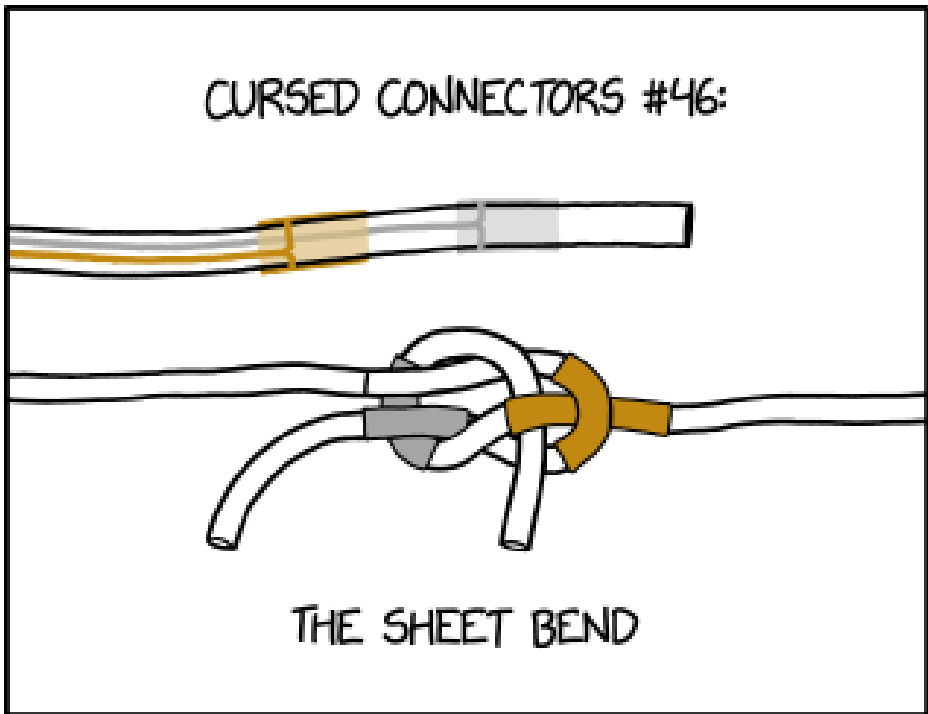
A left-handed sheet bend creates a much weaker connection, especially under moderate loads.

Explanation

This is the seventh installment in the series of Cursed Connectors and presents Cursed Connectors #46: The Sheet Bend. It follows 2642: Meta-Alternating Current (#120) after about 1,5 years. This is the longest break between two connectors, and so far it is also the last to be released. At the time of release this was also the lowest number used for a cursed connector, replacing 2495: Universal Seat Belt (#65) (with 2507: USV-C (#280) being the one with the highest number).

This comic shows two double-core cables being joined in a knot to make an electrical connection. The knot used to tie the two halves of the cable is a sheet bend, which is often used to join two ropes of different thicknesses, and explains the name for this type of cursed connector, which seems to be made by ensuring each cable end is terminated with identical electrical connections to the outer sleeving in a manner similar to various 'ring' connections in 'phone' connectors, but as significantly longer and more separated sleeves.

In contrast to more normal methods, Randall has proposed yet another of his 'cursed' connectors. This one requires no additional plugs, sockets, enclosures or even tools to use. Any two cables with such ends can be brought together and simply knotted together. This particular knot, and the specific spacing of its two external conductors, appears to be chosen in order to rather elegantly create consistent connections between

the respective contacts, with a minimum of fuss.

However, there are potentially many unaddressed but conspicuous problems with this connection method, thus rendering it a 'cursed' connector. Among the issues are:

- The need to have suitable ends to any cables, which would involve issues in the manufacture (and the materials used) as cable's cores must be separately tapped and reliably connected to an external length of conductive sleeving.
- The consistent ability of a cabler to tie the correct knot, which is a skill that will need practice. Done wrongly the electrical connections may not be made correctly, or at all (including as discussed in the title text).
- Even if initially tied correctly, knots can slip or distort when subsequently pulled more taut.
- Even if the user is a competent and consistent knot-tier, this is inherently more effort, and therefore less convenient, than the more usual practice of simply pushing two connectors together.
- The external conducting patches of the cable are an uncommon feature of electrical junctions, with issues in both high-power and low-power situations.

If the cables are supposed to carry high voltages, any bare conductors ought to be safely isolated from easy contact with equipment/people. In particular, plugs and sockets that carry anything approaching mains-voltages have active and passive elements integrated which protect the

person connecting or disconnecting the equipment. There is no physical precaution visible to protect the person tying or untying the cable from potential shock. Instead, they must rely upon the other end of the potentially 'live' cable being disconnected. And, when left unattended, there would continue to be a high risk of injury (including death), fire or more basic damage due to the lack of any proper physical isolation.

 Low-voltage cables that pass signals between equipment (e.g. networking data or audio signals) are susceptible to external contact disrupting the flow. Random static charges, built up and transfered into the connector, instead make other equipment or people the potential threat to the cabled-up equipment, causing disruption to the normal purpose of the cable, where a more standard plug-and-socket/hard-wired connection would not.

- The bending, twisting and rubbing of the cables each time the cables are connected and disconnected will very likely cause wear and damage over time.
- The knot provides a possible snag point by which the cable could be caught; anything which catches or tugs on the knot could cause disconnection.

The title text says that a left-handed sheet bend would provide a weaker connection. The difference between a left-handed and right-handed sheet knot is that the two free ends of the knotted 'cords' are in the same orientation for a right-handed sheet knot (here, both on the lower side of the image), but on opposite sides for a left-handed sheet knot. A left-handed sheet bend

provides less strength to the knot, due to the possibility of distorting (e.g. capsizing) and/or allowing one or both cables to pull through the knot.

This makes the title text a pun on the double meaning of "moderate load", which could be a moderate amount of physical tension applied through the cables or a moderate amount of electrical current passing through them. Together, it would be expected that tension drawing two conductive surfaces together would create less resistance between them, strengthening the electrical connection as well, but only if the knot holds as expected.

A knot was also the subject of the relatively recent 2738: Omniknot.

#2881: Bug Thread

January 15, 2024

SAME ISSUE HERE.

I'M HAVING THIS PROBLEM TOO. NONE OF THE POSTED FIXES WORK.

SAME

+1. SO FRUSTRATING.

I'M STILL HAVING THIS. DID YOU ALL EVER FIGURE OUT A FIX?

SAME PROBLEM AS EVERYONE. I TRIED THE STEPS IN THE POSTS HERE, HERE, AND HERE. NOTHING.

ADD ME TO THE LIST.

SAME. UGH. CAN'T BELIEVE THIS THREAD IS 5 YEARS OLD NOW.

WHERE DOES EVERYONE LIVE? DO WE WANT TO GET A BEACH HOUSE FOR A WEEKEND OR SOMETHING?

AT SOME POINT, YOU JUST HAVE TO GIVE UP ON FIXING THE BUG AND EMBRACE THE FACT THAT YOU HAVE DOZENS OF NEW FRIENDS.

After some account issues, we've added 6 new people from the beach house rental website support forum.

Explanation

A bug thread is an online discussion about unintended behavior in a program, also known as a bug. Bug threads may be found on bug trackers, such as Github or Bugzilla, on technical forums such as StackOverflow, or on general product user forums.

Most bug threads have a rule to only leave a comment if you have something insightful to add,[actual citation needed] such as being able to reproduce how the bug occurs or possible solutions to resolving it. In practice, this rule is often ignored and many threads end up with multiple people simply commenting that the bug still exists. It could be argued that this, in itself, is additional information, since it gives an indication of how widespread and/or persistent the problem is. Those who are perfectly content with a product have few reasons to participate in a bug thread, so those seeking help will tend to mostly read posts by the others who are, or have been, seeking help, if no one has provided a proper solution.

In this comic, multiple people are reporting the problem, as we can tell from their distinctive profile pictures. Most of the visible posts simply state the poster's inclusion in the list of those affected by the bug, either with a one word reply ("Same"), or a shorthand expression of emotion ("+1. So frustrating."). Some posters, however, do provide somewhat more useful information: existing troubleshooting methods haven't worked for them, with

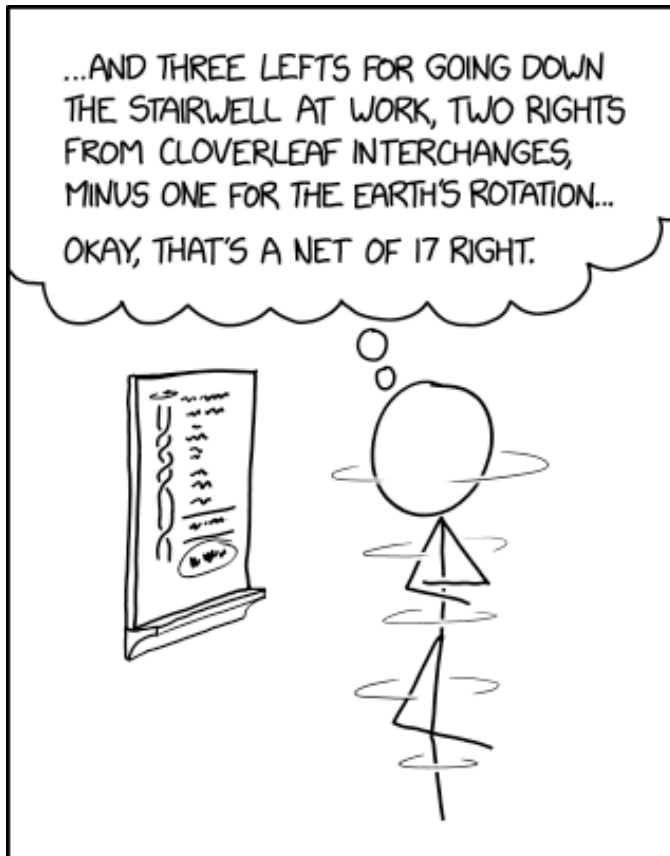one even providing three links to the specific solutions that they have already unsuccessfully tried.

Although we cannot see the unreadable timestamp information on the posts, one author (the penultimate, using a White Hat image) makes the observation that the problem has now been ongoing for five years. This is followed by a Cueball-identified user proposing that this group of like-minded individuals may enjoy meeting up at a beach house in the physical world. Whether this is Randall, or not, his own follow-up comic commentary suggests that bonding over such adversity is as good a reason for friendship as any.

The title text reveals that the meet-up was actually attempted. However, ironically, some of the participants seem to have run into "account issues" when trying to make their reservations, meaning that the website where they tried to rent the beach house wasn't working properly for them. Fortunately that website contained an online support forum like the one in the comic, and six participants from that forum ended up joining the social group. It is unclear whether the meet-up actually ended up occurring, but at least everyone involved now has some new friends.

979: Wisdom of the Ancients also refers to an online discussion thread about a bug, and 1305: Undocumented Feature also involves a tech support forum which is eventually used only for socializing.

#2882: Net Rotations

January 17, 2024

...AND THREE LEFTS FOR GOING DOWN THE STAIRWELL AT WORK, TWO RIGHTS FROM CLOVERLEAF INTERCHANGES, MINUS ONE FOR THE EARTH'S ROTATION...

OKAY, THAT'S A NET OF 17 RIGHT.

SPACETIME HEALTH TIP: REMEMBER TO CANCEL OUT YOUR ACCUMULATED TURNS AT THE END OF EACH DAY TO AVOID WORLDLINE TORSION.

For decades I've been working off the accumulated rotation from one long afternoon on a merry-go-round when I was eight.

Explanation

This is another one of Randall's Tips, this time a Spacetime health tip.

This comic may refer to a thing that some people with OCD do, which is to spin around to get rid of "net rotations," hence the title of this comic. Cueball (perhaps representing Randall?) takes this one step beyond the typical person with OCD - he calculates the net rotations each day and spins around at the end of the day to cancel this out. In this case, he would be spinning left 17 rotations to return to zero.

The offered reason for the necessity to do this is a physics joke: the reference to spacetime and to one's "worldline" has to do with relativity and the Einstein-Cartan theory, which is an extension of Einstein's general relativity. The theory suggests a coupling between the intrinsic spin of elementary particles (fermions) and the torsion of spacetime, and this comic appears to humorously extrapolate this idea to even supermolecular structures like a human, telling readers to "cancel out your accumulated turns at the end of each day to avoid worldline torsion", where in reality, it is highly unlikely the spin on such a large scale would cause any torsion in anyone's worldline, or their path traced by a particle or observer in spacetime.

A mobile device with position and orientation sensing might be able to keep track of one's net rotations,

eliminating the need for calculations. One would need only to do one's spinning while monitoring the device to see when it returned to zero.

The caption suggests that this is healthy and necessary/highly recommended to do this. However, most people don't, and most people are still OK.[citation needed] In fact, xkcd's own characters are perfectly OK with accumulating net rotations and similar topological excesses.
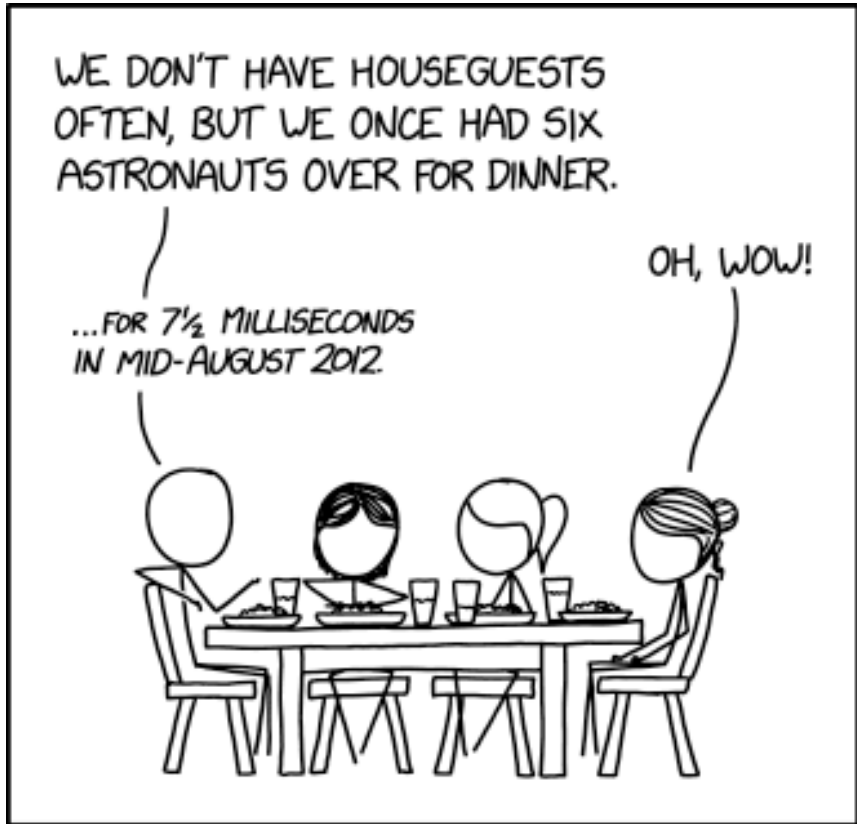
Possibly a reference to the 1966 novel, The Revolving Boy by Gertrude Friedberg whose protagonist suffered from being out of correct positioning depending on the number of turns he was forced to make in his everyday life.

The relationship between spinning and spacetime was formerly discussed in 162: Angular Momentum.

The title text mentions that Cueball was on a merry-go-round when he was eight and he accumulated so many rotations that he's still trying to counter these rotations to this day.

#2883: Astronaut Guests

January 19, 2024

WE DON'T HAVE HOUSEGUESTS OFTEN, BUT WE ONCE HAD SIX ASTRONAUTS OVER FOR DINNER.

...FOR 7½ MILLISECONDS IN MID-AUGUST 2012.

OH, WOW!

IF YOU SPEND ENOUGH TIME LOOKING AT ORBITAL RECORDS AND PROPERTY LINES, YOU CAN MAKE THIS CLAIM IN A LOT OF PLACES.

They didn't bring us a gift, but considering the kinetic energy of a bottle of wine at orbital speed, that's probably for the best.

Explanation

In this comic, Cueball, Megan, Ponytail, and Hairbun can all be seen eating dinner together. Presumably, Ponytail and Hairbun were invited over for dinner, as, to impress them, Cueball misleadingly claims that they previously "had six astronauts over for dinner." Normally, this would be interpreted as the astronauts being friends with the hosts (which confers social prestige), going inside their house, and eating. As it turns out, the astronauts only briefly passed overhead while in orbit, and, by chance, this happened during dinnertime. This is a pun on the word "over", as the personnel of the International Space Station are overhead when it passes above you; yet they did not go "over to someone's house" in the sense that English speakers would usually assume.

Cueball may also be considering the property lines to extend up indefinitely, causing the astronauts to technically be at their house despite being hundreds of miles away, vertically.

The astronauts in question were presumably occupying the International Space Station, which has an orbital period of between 90 and 93 minutes (depending on its altitude) or 5400 to 5580 seconds. If the astronauts were "over" for 7½ milliseconds, that would be somewhere between $1.34\text{x}10^{-6}$ and $1.39\text{x}10^{-6}$ of an orbit. Earth's circumference (at the equator) being approximately 40,000 kilometres (24,850 miles), the station was apparently "over" for a ground distance of between 53.9

m and 55.7 m (177 to 183 feet). That would imply quite a large property, but may also consider the astronauts' locations within the ISS, which is 109 m (356 feet) long. (The effect of angular size is small in this case because the ISS's elevation is small compared to the radius of the Earth. The route traced by the ISS in orbit is only slightly larger than its projection at ground level.)

The caption makes Cueball's statement even less impressive, alleging that statements like it are correct in many places. This would make it uninteresting as a coincidence. It can only happen for latitudes of less than 51.64° north or south, which is as far as the orbital inclination of the ISS takes it, leaving almost 21.6% of the Earth's surface never directly "over"ed. Nonetheless, these areas of the globe will be, overall, significantly more sparsely populated than those that are "over"ed, meaning that the claim could be made in much more than 78.4% of places, assuming that by "places" we mean "properties where people are likely to be having dinner".

The title text suggests that Cueball didn't want a gift (a bottle of wine) from the astronauts. The kinetic energy of a 1.2 kg (full) bottle of wine travelling at the linear velocity of the International Space Station (8000 m/s) is on the order of 40 megajoules. The gravitational potential energy of that mass on the Earth's surface (equatorial radius of 6,378 km) is 75.08 MJ, and its gravitational potential energy at an elevation of 408 km is 70.56 MJ, a difference of 4.52 MJ, and that would be converted to kinetic energy if it were to fall. For comparison, the kinetic energy of a fully loaded

semi-truck (max legal weight 80,000 pounds or ~36 tonnes) at 70mph (110km/h; a typical highway speed limit for passenger cars) is around 17 megajoules. A bottle with more than 2½ times the kinetic energy of that would be hard to keep on the table, and would likely do damage to people or things that tried to keep it there.[citation needed] However, this would assume that the bottle somehow survives its descent through the Earth's atmosphere intact, which seems unlikely.

This comic was posted the same day as the American release of a film set on the ISS (conveniently named I.S.S.), and just a day after the latest flight to the station by a Crew Dragon flight had temporarily increased the occupants from the normal seven residents to eleven.
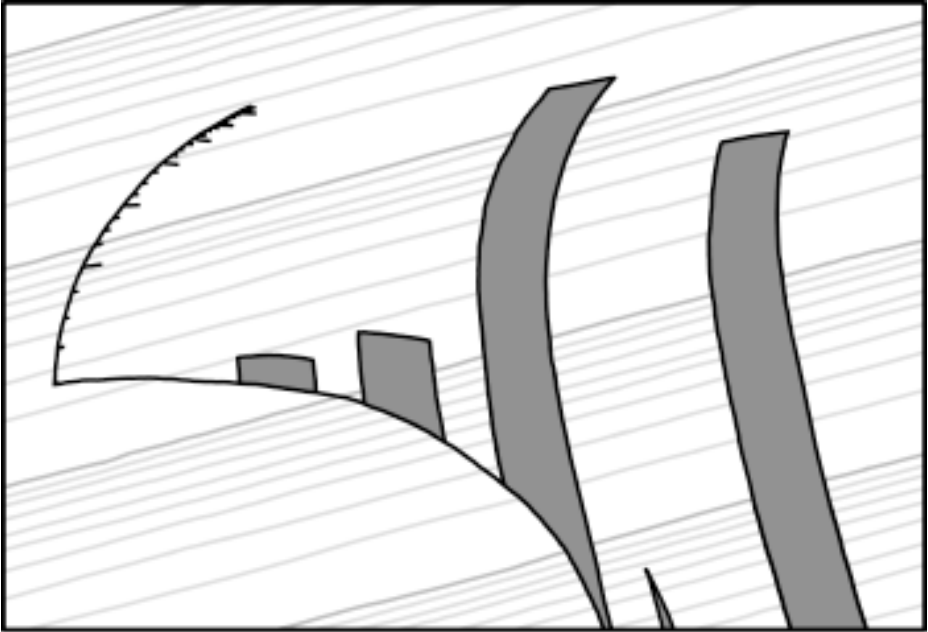
THERE'S ACTUALLY NO RULE IN MATH THAT SAYS YOUR LOG SCALES HAVE TO BE ALIGNED WITH YOUR GRAPH AXES.

A video can have a log scale that's misaligned with both the time AND space axes.

Explanation

In the comic, we see a background distribution of straight and parallel (but notably off-orthogonal) lines, such as might normally define the log-magnitude on a log-log or semi-log graph. But there are no perpendicular gradations and the bar graph drawn upon it appears to have no relation with the background, drawn distorted in an almost Dalíesque manner, as if it were a projection of one twisted in 3d space. Both its bars and the base/vertical axes seem to have no relation to the supposed underlying log-scale.

With the slight exception of the bar tops crossing the log lines at an angle, and the curved vertical axis having graduation ticks that bear no linear or log relation with the intersecting background, the distorted bars only travel unidirectionally across the underlying parallels and could feasibly be read as indicating a definitive magnitude (or range) of some kind. Or at least could with number-labels to give an idea of what values to associate with each log-line. That two bars appear from outside the frame of the comic (the base axis having fallen out of the bottom of the frame) might not even matter, so long as we can work out what quality or sample each of the bars represents (being similarly unlabeled).

The humour in the comic is that a more practical log-chart can be seen as the result of logarithmically compressing a normal chart in one or both axes. Normal

parallel and perpendicular axes remain straight lines when doing this; lines that aren't parallel or perpendicular to the squishing process get turned into curves of the exact kind depicted. A plot can be made according to measures not consistent with the graph axes, especially where other factors dictate the plotting, but then it is more common to make use of variant grid systems.

Skewed log charts are real and occur in fields of science with useful applications. For example, a "Skew-T log-P diagram" depicts the relationship between temperature and pressure of a parcel of air in the atmosphere. On this chart, the x-axis is skewed with relation to the rest of the graph, and its isotherms, or lines of equal temperature, slant diagonally upwards and to the right of the diagram. The y-axis is normal and represents pressure on a log scale. A more detailed explanation can be found here, and there are several related pressure/temperature charts which optimise the dimensional comparisons and skewings to allow for the results of somewhat codependent variables (such as normal changes along a slice of altitudes) to produce lines that are more recognisably consistent, or revealing of actual signature changes that provide more key information to those who study such diagrams.

The title text further reinforces the concept of misalignment by stating that the time axis represented by the progressive changing of a moving image can be misaligned against (by the other elements of the data within the video itself, including any log scale element),

adding at least one further dimension through which to twist and skew axial and non-axial components of such a dynamic graph.

#2885: Spelling

January 24, 2024

WHEN I CAN'T SPELL A WORD I USUALLY JUST GOOGLE AND COPY AND PASTE IT FROM THE RESULTS.

YEAH, BUT I CAN'T DO THAT *HERE*!!

WHY SPELLING "PLAGIARISM" IS ESPECIALLY HARD

Any time I misspell a word it's just because I have too much integrity to copy answers from the dictionary.

Explanation

Search engines like Google offer the correct spelling of most misspelled words. Some people get help with hard-to-spell words like "plagiarism" by entering their best guess into Google, then copy-pasting the correct version.

Cueball has an unusually strict interpretation of plagiarism in which copying the individual word "plagiarism" without attribution would be plagiarizing, and this misplaced integrity makes him morally opposed to doing so.

He also does not consider the option to cite his Google search of the often misspelled word as a source when including the correct spelling "plagiarism" in his document:

The title text implies that Cueball's absurdist view of plagiarism applies much more widely when he says he only ever misspells words because he has too much integrity to copy the spelling from the dictionary, an act he also considers to be plagiarism. Simply using the dictionary to spell a word correctly or lookup its definition is not plagiarism and does not require a citation. Any style guide or professional editor would advise Cueball that correct spelling is much preferred to incorrect spelling or superfluous citations.

Note that while spelling assistance should not be cited,

citing a dictionary can be appropriate when using the entry associated with a word, for example:

- Providing a definition: If you're using a definition from a dictionary to make a point in your writing. This is because the definition is serving as a source of evidence or support for your argument.
- Etymology or historical usage: If you are discussing the etymology or historical evolution of a word.

"Plagiarise" rather than "plagiarize" is the common spelling in many parts of the English-speaking world. Search engines may localize(/localise) the appropriate spelling(s) based on the user's (presumed) location.

A common misspelling of "plagiarism" is "plagerism", perhaps because of the way the word sounds when pronounced.

#2886: Fast Radio Bursts

January 26, 2024
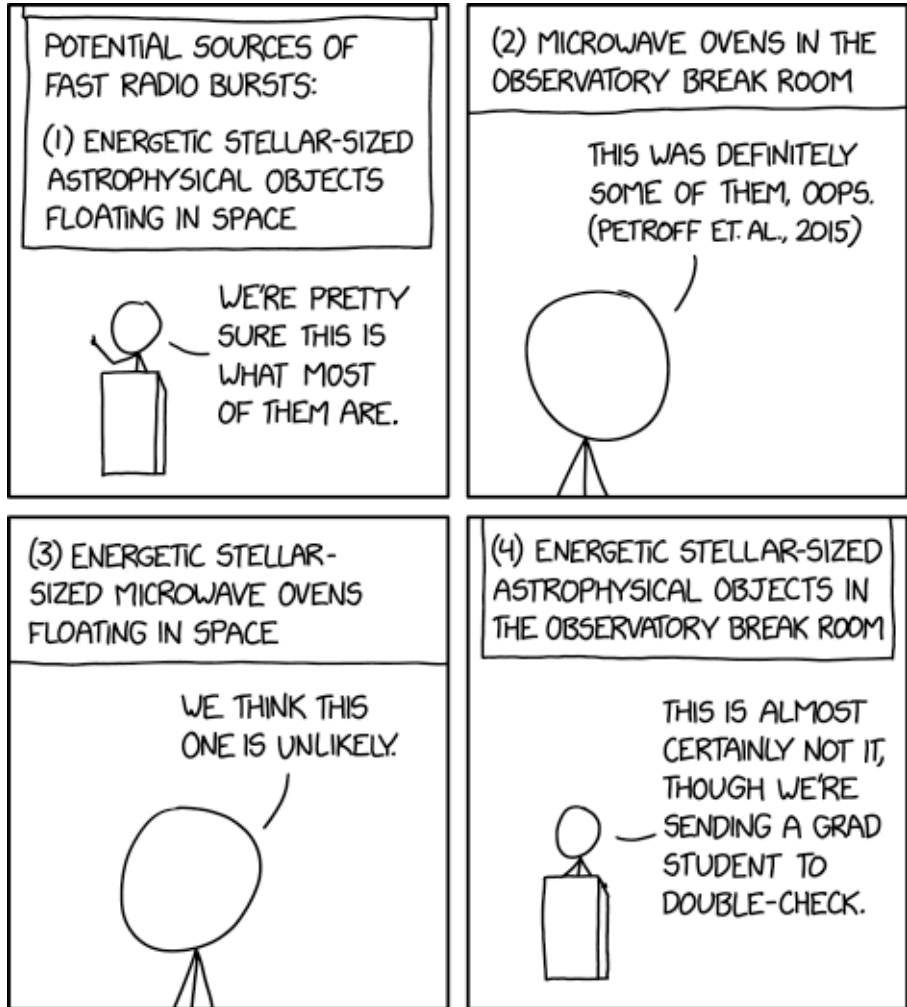
Dr. Petroff has also shown that the Higgs boson signal was actually sparks from someone microwaving grapes, the EHT black hole photo was a frozen bagel someone left in too long, and the LIGO detection was just someone

slamming the microwave door too hard.

Explanation

Cueball is giving a presentation, stating the different sources of fast radio bursts, which are short high-energy signals which have been detected by astronomers, but whose sources are not known. His team is pretty sure that most of these bursts are energetic stellar objects in space - that is, astronomical phenomena.

He then says that some of them are caused by microwave ovens, citing Dr. Emily Petroff's work on identifying the apparent source of "perytons" at the Parkes Observatory. These are signals similar to fast radio bursts, but which originate on Earth and not in space; initial hypotheses included atmospheric effects related to lightning and passing aircraft, but they were eventually identified as a much closer range signal from microwaves escaping as the oven door was opened inside the observatory.

After that, he explores two further options, combining attributes of the previous two:

• Energetic stellar-sized microwave ovens floating in space; this is unlikely since microwave ovens typically are not stellar-sized and all known microwave ovens originate on Earth rather than in space. (There is a microwave oven installed in the Chinese Tiangong space station, but it appears that the ISS is less well equipped than that. Neither facility is ever likely to have room for 'stellar-sized' equipment of any kind.)
• An energetic stellar-sized object in the observatory

break room would be surprising, as we have yet to see a break room large enough to contain a stellar-sized object. Although unlikely, he says he sends a grad student there to double-check. Presumably, the student is being sent rather than Cueball himself both because it is unlikely to give useful data, and because if there is indeed energetic stellar plasma in the break room, the million-degree temperatures would probably kill anyone who enters it, and grad students are disposable when compared to researchers.

Note that, as well as the universe-sized Cosmic microwave background radiation, there are various microwave-bright Pulsars and other strong microwave signals originating from actual stars, but no reason to believe that they are deliberately purposed/engineered as any actual oven, despite misleading language sometimes employed by those in the field.

The title text references several other discoveries, with Dr. Petroff suggesting explanations based on microwave ovens for each of them, as was the case with her discovery:

- The apparent detection of the Higgs boson at the Large Hadron Collider was actually someone microwaving grapes, which generates plasma
- The image of a black hole captured by the Event Horizon Telescope was a burning bagel (a notably ring-shaped bread product with the charred portion being black)

- LIGO (the Laser Interferometer Gravitational-Wave Observatory) did not detect gravitational waves, but was instead disturbed by someone slamming the microwave door too hard

In each case, these are highly improbable - for instance, LIGO used a complex suspension system, and two sites (one in Louisiana and one in Washington State) comparing signals, to rule out such interference. The real Dr. Petroff has not made any such claims.[citation needed]

See 2289: Scenario 4 for a similar situation.

#2887: Minnesota

January 29, 2024
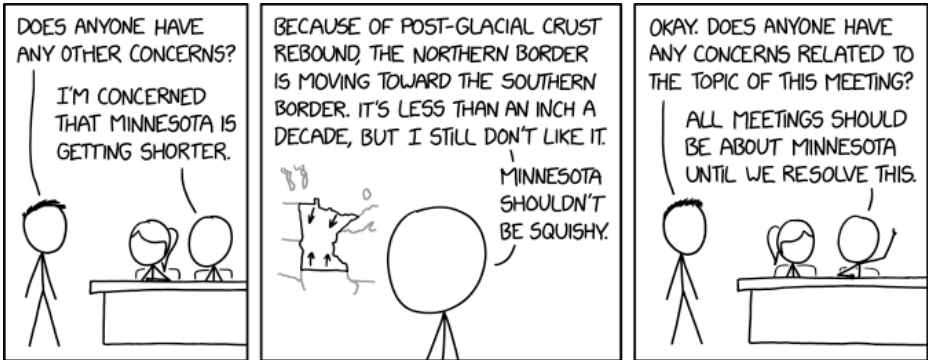
In addition to 'squishy', after reviewing my submitted intraplate ground motion data, the National Geodetic Survey has politely asked me to stop using the word 'supple' so often when describing Midwestern states.

Explanation

Hairy, Ponytail, and Cueball are in a business meeting of an unknown nature, but one which (it transpires) is unrelated to either geography, geology or geopolitical boundaries. Hairy asks if anyone has any other concerns, a common enough question to ask when trying to ensure that nobody at the meeting has still something to say that had not already been covered directly by the agenda or the resulting discussions.

Cueball voices an opinion on Minnesota. Due to the post-glacial rebound present in Minnesota, this US state is apparently slowly decreasing in size. The humor comes from the fact that this may be a genuine concern to Cueball, but is completely unrelated to the topic of the meeting, is not really a 'problem' that has any practical significance, and in any case there is also no reasonable way to prevent this.[citation needed] And yet Cueball clearly finds it important enough that "all meetings should be about Minnesota" until the 'problem' is solved.

The title text implies that Cueball has also brought this issue up to the National Geodetic Survey; rather than commenting on his data or findings, they have simply requested that he stop using suggestive language in his papers. ("Supple" and "squishy" are sometimes used, especially in erotic literature, to describe certain body parts.)[citation greatly appreciated]

The Midwestern states, particularly in areas like the New

Madrid Seismic Zone, are subject to the movement of tectonic plates well within a tectonic plate boundary. While these areas are typically less active than boundary zones, they can still experience significant seismic activity. The flexible way the Earth's crust in these regions responds to tectonic stresses – gently stretching and flexing over centuries in response to deep stresses – could imaginatively be described as "supple."

Minnesota's northern border is legally defined in part by reference to geographical features, most notably Lake of the Woods and a chain of rivers and lakes connecting it to Lake Superior. As such, movement of these features due to glacial rebound may indeed be reducing Minnesota's size at a very gradual rate. Minnesota's southern border, in contrast, is legally defined as a line running at 43º 30′ N, which would not be affected by the motion of the land. Indeed, it is possible that glacial rebound is effectively moving land out of Minnesota and into Iowa, again at a very gradual rate.

#2888: US Survey Foot

January 31, 2024
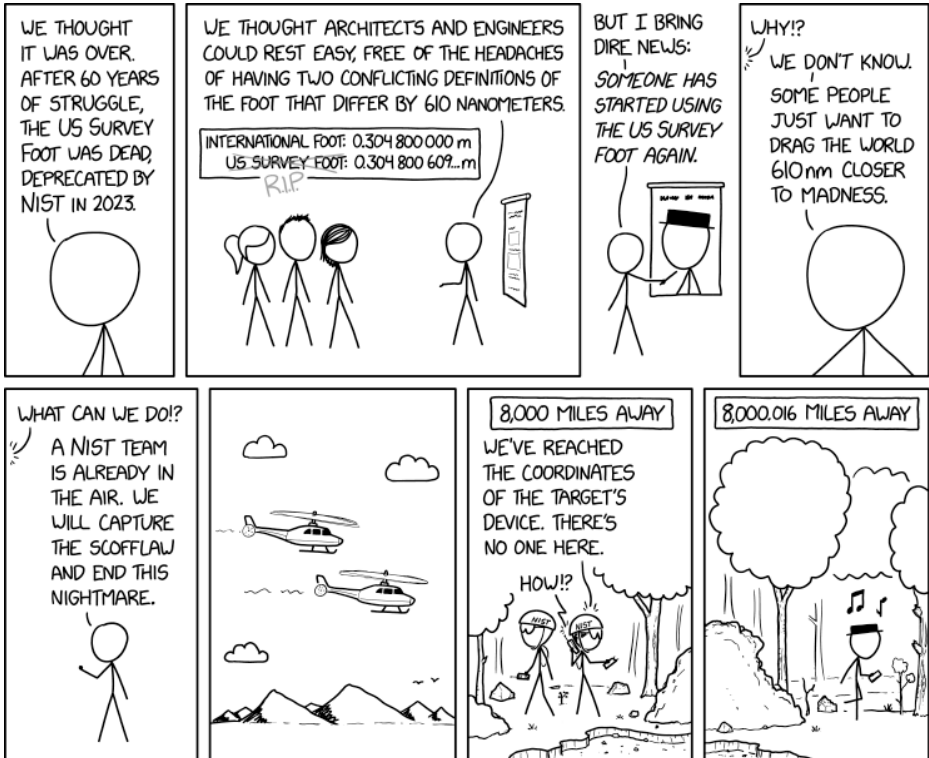
Subway refuses to answer my questions about whether it's an International Footlong or a US Survey Footlong. A milligram of sandwich is at stake!

Explanation

This comic pokes fun at the difference in length between the US Survey Foot and the International Foot. After Carl Edvard Johansson's gauge blocks in 1912 led to an international agreement in 1959, the foot has been defined to be exactly 0.3048 meters, whilst the US survey foot continued to use the definition of 1893, making it a bit longer than the international foot at 1200/3937 meters. However, the difference between the two is proportionately too small to be meaningful for most purposes, as they differ by only 2 parts per million. At foot-length scales, the difference is a fraction of a micron, with longer measures (where the error grows to a notable degree) requiring an already excessive implied precision likely to mismatch its true accuracy. Some engineering or scientific applications may involve such tolerances, but would be expected to consistently use some more modern standard of measurement, such as SI (the Metric System), to avoid such confusion.

In the third panel, Cueball says that someone is using the survey foot again. It turns out to be Black Hat, acting in a way that sounds very typical for him. Cueball claims that he is drawing the world 610 nm closer to madness, which is about the difference per foot between the two measures. Cueball, outraged, then says that the National Institute of Standards and Technology (NIST) will capture Black Hat to stop him from using the US survey foot. One joke here is that his coordinates show that he is 8000 miles away, but since he is using the US survey foot,

he is 0.016 miles (around 25.75 meters or 84.48 feet) away from the search team, making them unable to find him at that exact spot. They are probably at the same lake in the last two frames, with maybe only some bushes separating them; a good strike team would likely keep looking in the area, but perhaps being strictly NIST-trained to adhere to particularly exacting standards has ironically made them vulnerable to the same inaccuracies that they are supposed to be preventing.

Part of the joke is the imaginative idea that NIST employs and dispatches strike teams to apprehend persons that use incorrect measurements. This may be a play on words about the Nuclear Emergency Support Team, or "NEST", a United States Department of Energy group who respond to nuclear and radiological emergencies such as reactor accidents or nuclear terrorism, and who might reasonably have access to resources such as the helicopters depicted during a crisis.

The title text references a 2013 lawsuit over the length of a "Footlong" sandwich sold by the Subway fast food chain. However – in contrast to the issue at stake in that lawsuit – the difference in length between an 'international footlong' sandwich and a 'US survey footlong' sandwich is far below the precision or accuracy by which sandwiches are usually produced, making it understandable that Subway would not think it necessary to clarify which definition of 'foot' they use for their products.

Absurd outcomes from updated survey standards was

also the topic of 2920: Survey Marker.

Explanation of the comic's underlying assumptions and implications[edit]

Randall appears to be playing a bit fast-and-loose here. To make this joke work implies a rather imaginative situation: that both Black Hat and the searchers have set their devices to measure and report location in reference to the same location (the place where Cueball is, at one end of the 8,000 mile measurement) and not just use a satellite navigation system like GPS and lat/long like every other smartphone on the planet.

In the unlikely event that the searchers' phones measure and report location in reference to Cueball's location, evidently Black Hat has also overridden his device's in-built GPS to report its location in reference to Cueball's location as a way to toy with him and the NIST teams, and then traveled EXACTLY 8,000 survey-foot miles away, knowing NIST would be able to track him and that a team would be sent in pursuit. After all, Black Hat is known for his preternatural powers of mischief.

The punchline of the comic still doesn't make much sense though. The difference between the two definitions of the foot (8,000 miles vs 8,000.016 miles) is a little under 85 feet, and the background of the last two comic panels suggests that Black Hat and the NIST team are both standing next to the same pond on the other side of a bush or rock. Given that humans can easily see for miles, it is extremely unlikely that the NIST team would not be able to see Black Hat walking away. Even if they could not on the ground because of the rock/bush in the way, they should have easily done so from the helicopter as they approached.

Furthermore, Black Hat is shown as humming or singing due to the musical notes by his head, and once again humans can easily hear someone humming or singing from about 85 feet away in a quiet forest.

Though Cueball's location is not specified, one potential location is NIST headquarters in Gaithersburg, Maryland, or another governmental location, perhaps in the Greater Washington Area where most US government agencies and departments are headquartered. These options are supported by the panel in which Cueball mentions a NIST team is on their way and brags that "we" are going to capture him. This language implies that Cueball either works for NIST or for a larger effort in which NIST is a partner. These location options are also supported by the fact that Cueball's location is used for the origin point of the 8,000-mile measurement, suggesting that he's speaking at a flagship location and not a random office building.

The use of helicopters — which cannot fly 8,000 miles unaided — also suggests an imaginative situation in which NIST teams with access to helicopters are distributed around the globe, perhaps at US air bases and on US aircraft carriers.

Real world examples[edit]

In the early 2000s, Survey Foot/International Foot conversion issues created difficulties in the civil engineering industry after a commonly used CADD design software package changed how it processed units. Prior versions of the software program Microstation were unit-agnostic, relying only on absolute coordinates assigned to elements from survey data. Starting with Microstation Version 8, internal software calculations were

performed entirely in metric units and relied on a units definition file to seamlessly convert to the unit system being used for a project. The default options in the program being "Foot" (i.e., International Foot) or "Survey Foot", many users were unaware of the difference and selected "Foot" even when a project's field survey was performed in survey feet. In the US, most states have their own coordinate systems, referred to as State Plane Coordinates, to correct for the approximation of projecting the Earth's spherical surface into a cartesian X,Y plane. Some states have coordinate zones which span their entire length, so a project's coordinates can be millions of feet from the origin, a scale on which the minuscule difference between Survey and International feet conversion becomes whole feet.

In another famous example, a building in Arizona was required to be built one story shorter than planned. The building was going to be 20 stories tall and almost in line with an international airport runway. It was designed to be one foot north of the FAA mandated flight path for runway approaches, which it would otherwise violate due to its height. However, the building was surveyed in international feet (the legal standard in Arizona) while the flight path was defined in survey feet (used nationally by the FAA). The baseline that defined coordinates in this part of Arizona was about a million feet away, which added up to a difference of about two feet. As a result the building would have been inside the FAA flight path, and to avoid this the building had to be reduced to 19 stories so it was below the exclusion zone.

#2889: Greenhouse Effect
February 02, 2024
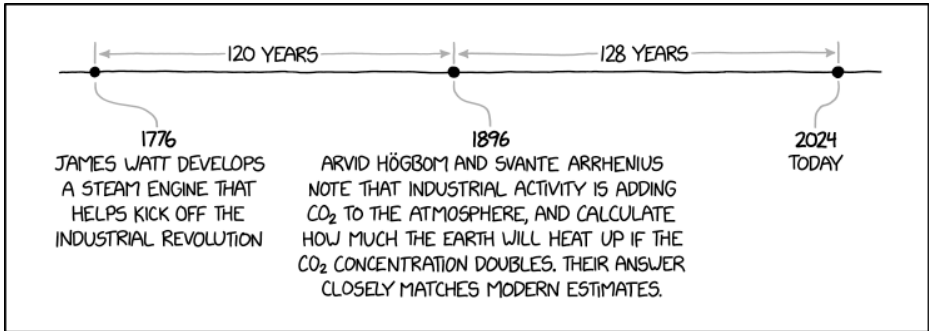
WE FIGURED OUT THE GREENHOUSE EFFECT CLOSER TO
THE START OF THE INDUSTRIAL REVOLUTION THAN TO TODAY.

Once he had the answer, Arrhenius complained to his friends that he'd "wasted over a full year" doing tedious calculations by hand about "so trifling a matter" as hypothetical CO2 concentrations in far-off eras (quoted in Crawford, 1997).

Explanation

This comic has climate change as its topic, a recurring theme on xkcd. There is no 'joke' per se, just a wry (and serious) observation on the timeline of climate change, and our understanding of it. The fact in question here is when science became aware of anthropogenic global warming and its primary cause.

The comic depicts a timeline with three events:

- The introduction of the Watt steam engine in 1776. The comic takes it as the start of the Industrial Revolution, and the event that most directly ushered in the boom of fossil fuels' burning.
- The first quantitative prediction of the greenhouse effect by Svante Arrhenius in January and April 1896 (that doubling CO_2 concentration would increase mean temperature by 5 to 6 °C, depending on latitude). Arrhenius drew on and included a summary of Arvid Högbom's 1894 Swedish article, which dealt with carbon cycle over geological periods and first estimated annual global carbon emissions.
- The present day, early 2024.

As the caption points out, less time elapsed between the start of the Industrial Revolution and the work by Arrhenius, than has elapsed since then. Some present-day climate discussions may cite a 1957 paper by Revell and Seuss as "the starting point" for modern inquiries into global warming. While it was more advanced and

detailed, the comic notes "we figured out the greenhouse effect" 61 years prior; see both Robbie 2018 and even longer History of climate change science which includes earlier, qualitative works.

The implication, consistent with other climate change themed xkcd comics, is that humans have taken insufficient action to stop global warming despite knowing about it for more than a century, and understanding, at least intellectually, the consequences of inaction.

The title text portrays Arrhenius as dismissive of his work. A reading of the reference cited (page 8 in Crawford 1997: 'Writing to a friend at the end of , he found it "unbelievable that so trifling a matter has cost me a full year".') suggests instead that Arrhenius was complaining about the unanticipated difficulty of answering what he thought initially was a simple question, about the historical (geological time) connection between carbon dioxide concentrations and global temperature. Per this reading, Arrhenius's complaint was about the work required to achieve the result, not about the significance of the result. His interpretation of the significance, though, differed from today's (page 11 in Crawford 1997): "[Global warming will] allow our descendants, even if they only be those of a distant future [estimating the doubling time as 500 years], to live under a warmer sky and in a less harsh environment than we were granted".

#2890: Relationship Advice

February 05, 2024
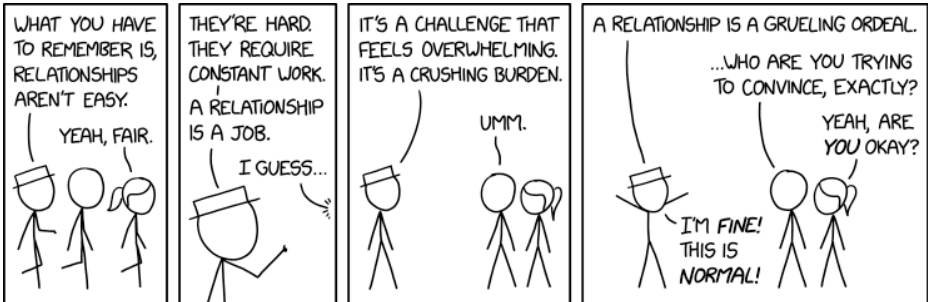
Good to be a little wary of advice that sounds too much like a self pep talk.

Explanation

In this comic, White Hat, Cueball, and Ponytail can be seen having a conversation about relationships. White Hat expresses the opinion that "relationships aren't easy". The others accept this advice, which is generally accepted as a reasonable view: two people are always going to have at least some difference in opinions, desires and needs that need to be communicated, negotiated and worked out. This requires mutual effort and some level of compromise in any healthy and successful relationship.

In the subsequent frames, however, White Hat continues to push the matter, describing relationships in increasingly unpleasant terms, starting with calling them "constant work" and ultimately calling it a "grueling ordeal". Cueball and Ponytail correspondingly agree with him less, and instead begin to worry about him.

White Hat's views on what is necessary and appropriate in relationships appear to go to unhealthy extremes. While his initial comments about relationships requiring efforts are reasonable, the notion that relationships consist of endless, overwhelming effort is not, for most people, though for some people who experience significant asociality this can be how most relationships feel. However, Cueball and Ponytail appear to suspect that White Hat may be describing a relationship that he's currently in or that has severed, and trying to rationalize an unhealthy situation by telling himself that "this is normal".

When someone is in an abusive relationship, they may struggle to see that the relationship is abusive, often confusing genuinely destructive behavior with normal relationship troubles. There are various reasons this may occur. Some people experience traumatic bonding, some have spent so much time in or around unhealthy relationships that they've come to seem 'normal', and some experience various forms of codependence. For people in such situations, help from friends and/or professional counselors is often necessary to allow them to even identify the situation they're in, and particularly to separate themselves from the situation.

Seeing Randall's often negative thoughts on Valentine's Day and the problems it produces, it may not be a coincidence that this comic was released only nine days before the event.

The title text explains that advice which focuses on remaining upbeat in a bad situation (like a "pep talk"), should give others pause. There's a good chance that the person giving such advice is trying to convince themselves that their situation is alright, rather than providing useful guidance for others. In this comic, this sentiment is seemingly applied to White Hat, whose "relationship advice" may be much more personal than such advice should reasonably be, and the reader is thus warned to take advice like this with a grain of salt. This is similar to 449: Things Fall Apart where Cueball tells Megan "I love you" repeatedly and Megan points out he's only saying it to reassure himself rather than express it to her.

This comic's title is reminiscent of Randall's Tips comics. Here, though, there turns out to be no actual advice or tip, and thus not part of the tip category.

#2891: Log Cabin

February 07, 2024
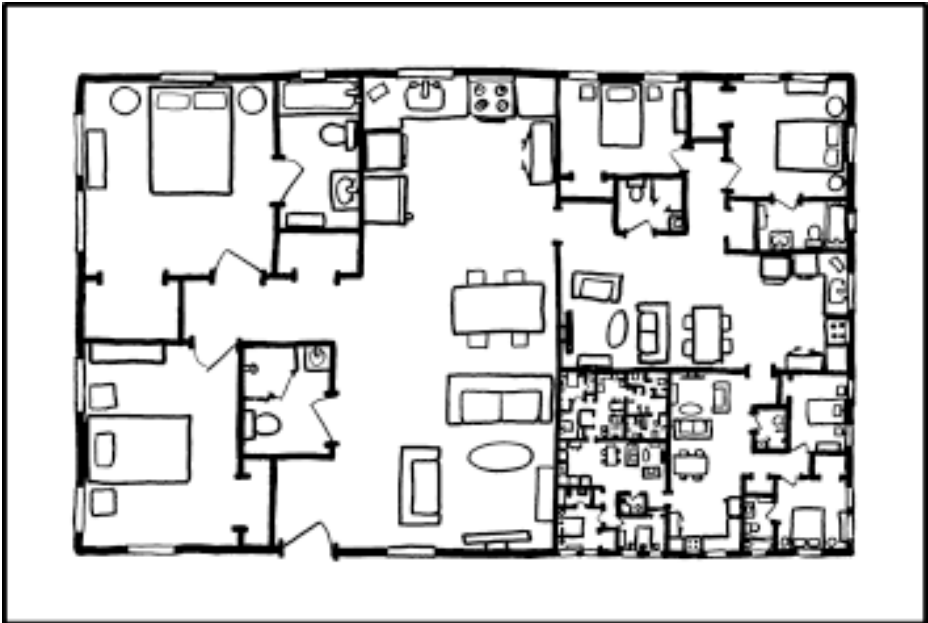
LOG CABIN

I'm sure the building inspectors will approve my design once they finally manage to escape.

Explanation

This is a comic featuring a floor plan, presumably of a log cabin, and a pun on the word "log". The odd part about it is the right half, which appears to be infinitely recursive copies of the building, a self-similar fractal. The house as a whole represents a golden rectangle with a side ratio of the golden ratio ($\Phi = (1+\sqrt{5})/2 \approx 1.6180339887...$), with successively smaller living areas (further subdivided into rooms, to a common but shrunken and rotated plan) being square adjoined by a golden-rectangle of all smaller living areas in the manner of the areas defined by the classic Golden spiral diagram. The joke is that Randall is intentionally conflating the word "log" in the common phrase "log cabin," where "log" refers to the wood the cabin is made of, with a logarithmic spiral, as "log" is shorthand for "logarithmic".

Every square subunit of the premises consists of a main combined kitchen/lounge area, with an adjoining shower-equipped bathroom, and a hallway leading to a closet and two bedrooms (a double-bed one with en-suite bath-equipped bathroom, and another with a single bed; both having their own walk-in closet space). Between the kitchen and the dining table is the open doorway that serves as the entry into the next inwards level of the floorplan.

A visitor can also walk in a spiral by using the open doorways in the building plan.

In the title text, Randall says that he is confident that building inspectors will approve the design of his log cabin, assuming they can escape. As one moves deeper into the infinite spiral of architecture, the entire log cabin seems to be a denser labyrinth of rooms and hallways.

It is unknown how the inspectors lost in the inner rooms would shrink in the same ratio, and would only have to head out through the last doorway they walked in through (or two, if they're currently in the en-suite) and then exit each 'main' area in turn until they exited the building itself. If they have any trouble at all (other than rescaling themselves), it would be that there is always a further inward area that they might consider needs exploring to fulfil their inspection routine. This construction could imply folded spacetime. To perform a correct inspection, the inspectors might need sufficient relation that inner rooms are identical to the outer rooms, and to solve algebraic equations for various parameters.

It could have been that the repetition continued outside of what is drawn here, continuing to grow larger as it moves further out, except that only the top-level external entry has a door: the entries to each lower level only have open doorways marked with no door, and except for the clear marking of external windows on the first four iterations, with no internal ones (and therefore no equivalent windows on the subsequent iterations) precludes that possibility. In fact, the first iteration has windows on the 'southern' edge for the single bedroom and seating area, for which there are no equivalents on

any of the other iterations.

Log Cabin is also a classic quilting block, which starts with a tiny square and spirals outwards.

#2892: Banana Prices

February 09, 2024

"IT'S ONE BANANA, MICHAEL. WHAT COULD IT COST? $10?"
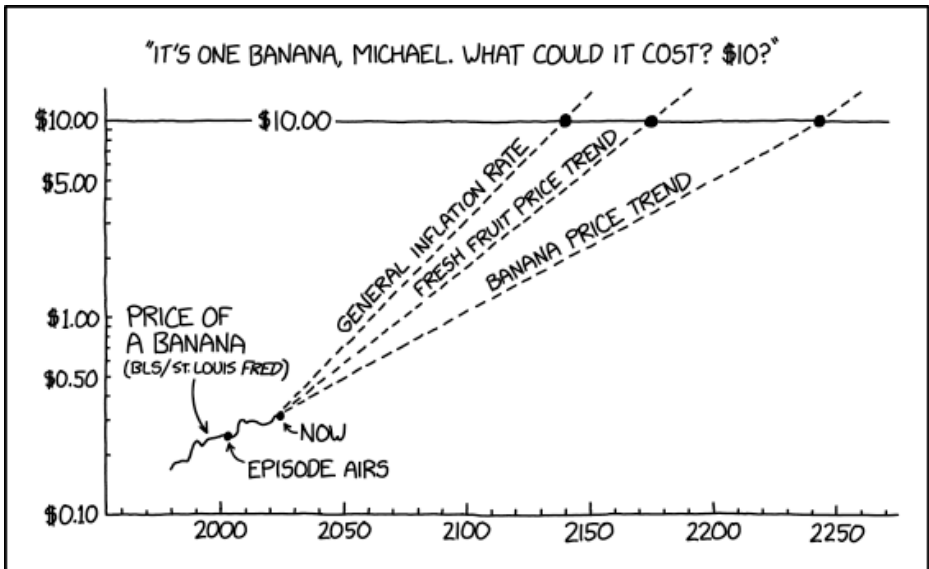
THAT LINE PROBABLY HAS ANOTHER CENTURY OR SO LEFT.

It's a linear extrapolation, Michael. How big could the error be? 10%?

Explanation

'It's one banana, Michael. What could it cost, $10?' is a line from an Arrested Development episode (Season 1, Episode 6, "Charity Drive", 2003) that became a well-known meme used to mock out-of-touch elites. The character who spoke this line (Lucille Bluth, a wealthy socialite) made a satirically high estimate for the price of a banana because she had never bought her own groceries. According to the graph, the banana price at the time of that episode was actually just under 25 cents, and the price at the time of this comic's publication (2024) is around 30 cents.

The comic is a wry observation that the irony of this sitcom line will "probably" be anachronistically meaningless in a century or so, presenting three predictions of banana prices over the next 250 years that each extrapolate from the current 2024 price using different long-term inflation rates.

The three extrapolations use (1) the general inflation rate (a value dominated by the cost of housing), (2) the inflation rate for fresh fruit, and (3) 45 years of historic banana prices. Those models present the joke becoming reality around 2140, 2170 and 2250, respectively.

The caption's claim that banana prices could exceed $10 in a century are based on the fastest rising extrapolation, the one for "general inflation." This extrapolation predicts a banana's price to rise from 30 cents to $10 in

approximately 115 years. This 115-year increase corresponds to an average long-term inflation rate of about 3.2%, close to the historic US average.

The reference to "BLS/St. Louis FRED" refers to The Bureau of Labor Statistics and St Louis FRED, widely respected sources of economic data. The Federal Reserve Bank of St. Louis maintains the FRED database; FRED stands for Federal Reserve Economic Data.

The title text continues the ignorant tone of Lucille Bluth to make two jokes.

It's not typical to plot commodity prices on a log-scale, but maybe Randall did this to allow himself to make this subtle "linear extrapolation" joke.

This comic uses several common xkcd themes:

- Log scales and their peculiarities are a recurring xkcd theme, and this is the second comic in a row to play with logarithms (the prior one being 2891: Log Cabin).
- It's also the second comic in the last four to involve predictions across centuries (see 2889: Greenhouse Effect).
- Extrapolation and interpolation, often absurd, are recurrent topics on xkcd.

Discussion of price references in fiction[edit]

It's common for fictional works to avoid mentioning actual prices or amounts of money. One reason is that presenting an actual amount risks the work becoming dated by inflation. A price that's

presented as surprisingly high can lose its impact as the value of money changes, making it difficult for a punchline or a dramatic moment to land. In this case, however, the number is so exaggerated (being around 40 times higher than the actual price of a banana), that it's unlikely for inflation to impact the joke in the immediate future. Twenty years after the episode first aired, the joke works just as well as it did.

While the graph is about ordinary bananas, technically Lucille may have been guessing the price of frozen and chocolate-dipped bananas, which sold for $1 to $4 in the early 2000s. The only thing this changes is the interpretation of her estimate as perhaps being slightly less out-of-touch.

Panama disease[edit]

The banana price can possibly be highly affected by the Panama disease:

#2893: Sphere Tastiness

February 12, 2024
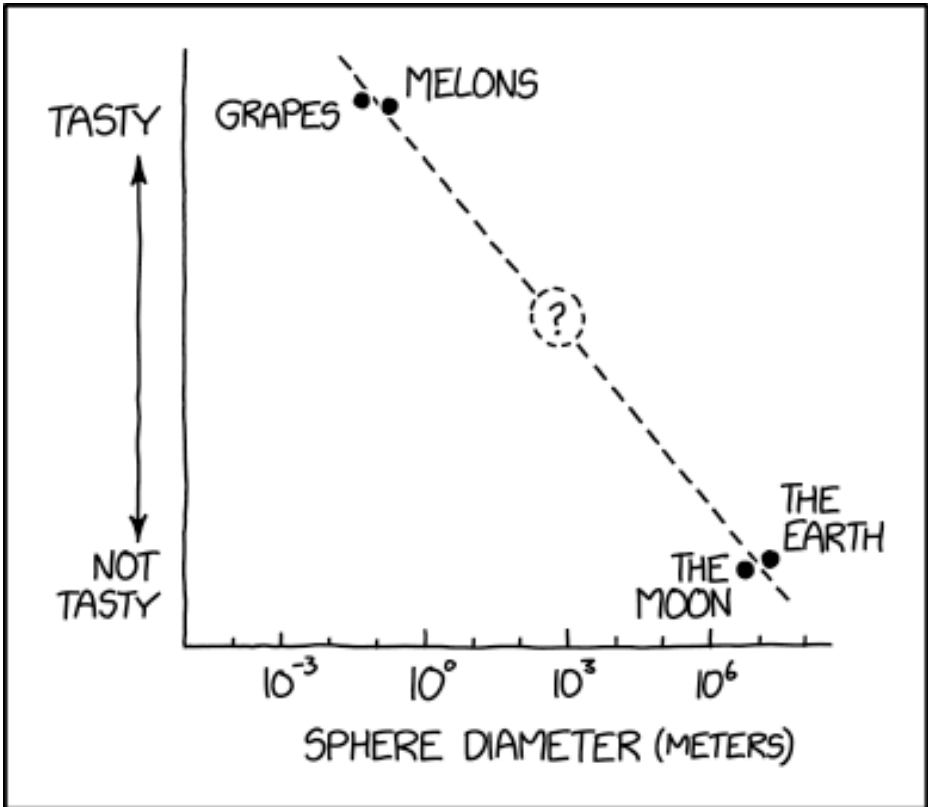
MY RESEARCH SUGGESTS THE EXISTENCE OF
AN 800-METER SPHERE THAT TASTES OKAY.

Baseballs do present a challenge to this theory, but I'm
convinced we just haven't found the right seasoning.

Explanation

This comic graphs the tastiness vs. the size of four roughly spherical objects: melons, grapes, Earth and the Moon. Based on the fact that melons and grapes are (in this context) relatively small and tasty to most people, and that planetary scale bodies are relatively large and made mostly of rocks and metals generally considered not remotely tasty,[citation needed] Randall postulates the existence of an intermediate body, one which is approximately 800 meters in diameter and "tastes okay".

This is the second comic in a row to feature fruit, graphs and predictions (after 2892: Banana Prices), and continues the theme of a logarithmic axis scale to facilitate plotting a linear regression. Here the line is interpolated between known data, rather than extrapolated beyond it. Such interpolation is quite common in scientific analysis, and is often useful, but this example clearly leads to a ludicrous conclusion. Using such ridiculous analyses to show the dangers of flawed and/or sloppy methodology is a common theme in xkcd.

There are multiple ways in which this analysis is flawed, and therefore why the conclusion is unsupportable:

- there are only four data points, which is insufficient to interpolate from.
- these clusters represent entirely different sub-classes of spherical object (fruit vs. astronomical bodies) while

other subclasses are not represented at all (the title text mentions this flaw).

- as tight clusters of similarly sourced data, it effectively reduces the data down to two useful data points. This also makes the choice of log-median interpolation unjustified.

- the 'tastiness' scale has no indication of what assessment (subjective or objective) it records. Nor does it even have graduations, making it unknown if the graph is linear-log or log-log (or otherwise), changing the implied meaning behind the choice of straight-line interpolation.

- according to astronaut John Young, who visited the Moon's surface during the Apollo 16 mission, "moondust doesn't taste half bad". (Although other Apollo astronauts likened its smell and taste to burnt gunpowder, so make of that what you will.)

The title text points out that baseballs seem to refute this theory since they're not usually thought of as tasty, but they're between the sizes of grapes and melons, which would place them in the bottom left of the graph, way off the fit line. Baseballs are typically made of a combination of a rubber or cork center wrapped in yarn, and covered by either horsehide, cowhide or synthetic leather. In point of fact, there are many, many common round objects that completely fail to conform to this graph, but rather than acknowledge that this analysis is fatally flawed, Randall uses special pleading to justify its exclusion from the graph, suggesting that the problem is that we lack "the right seasonings". While seasonings can

improve the taste of foods, it's implausible that the inedible components of baseballs would be rendered "tasty" with any conceivable combination of seasonings. Even if they could, there's no evidence that such would give them the proper level of 'tastiness' to conform to the graph. This argument lampoons the use of "cherry picking" and motivated reasoning, in which researchers include only data points which fit their hypothesis and make up reasons to exclude those which don't. This is obviously very poor science, but less exaggerated versions are all too common in scientific studies.

The comic refers to this plot as research. This is an exaggeration, since two clusters of paired points are rarely considered sufficient for research purposes. But plotting a justifiably sufficient quantity of data points on a logarithmic plot, and then drawing a line through them, is a common way to visualize an actual exponential relationship more comprehensibly. An example of that is the Gutenberg–Richter law where the magnitude of earthquakes (an intrinsically logarithmic scale) in a particular region is plotted together with the frequency of occurrence, typically resulting in a statistically significant straight line.

Other fruit opinions have previously been mentioned in 388: Fuck Grapefruit, but it is unknown what the line would be like if Randall included grapefruit.

Extrapolation and interpolation, often absurd, are recurrent topics on xkcd.

#2894: Research Account

February 14, 2024

APPLICATION FOR RESEARCH ACCOUNT

INSTITUTION: [OTHER/NONE ▽]

REASON FOR REQUESTING ACCESS TO OUR DATASETS:

[TO WIN AN ARGUMENT WITH SOMEONE IN A GROUP CHAT]

(SELECT ALL)
(DELETE)

[INDEPENDENT RESEARCH]

I NEVER KNOW HOW HONEST TO BE ON THESE FORMS.

Focus of your research: EXTREME PETTINESS AND UNWILLINGNESS TO LET ANYTHING GO

Explanation

Cueball has a longstanding craving to win online arguments and to prioritize these arguments (see 386: Duty Calls, one of Randall's viral comics). In the comic he is filling out a form to register for a research account. Such accounts are typically intended for people doing serious work in the relevant field, who need access to the materials provided to support that work. Cueball, however, has filled out "other/none" for institution, and "to win an argument with someone in a group chat" for "reason for requesting access to our datasets", making it clear that his interest is both petty and personal. While this may be honest, it doesn't match the assumed purpose, and he may be worried that it might mean that his registration would be rejected or subsequently cancelled. So he then selects all and deletes his previous justification, replacing it with "independent research", which is an accurate, if generic, explanation. Randall is undoubtedly familiar with such registration forms from doing background research for xkcd and What If?.
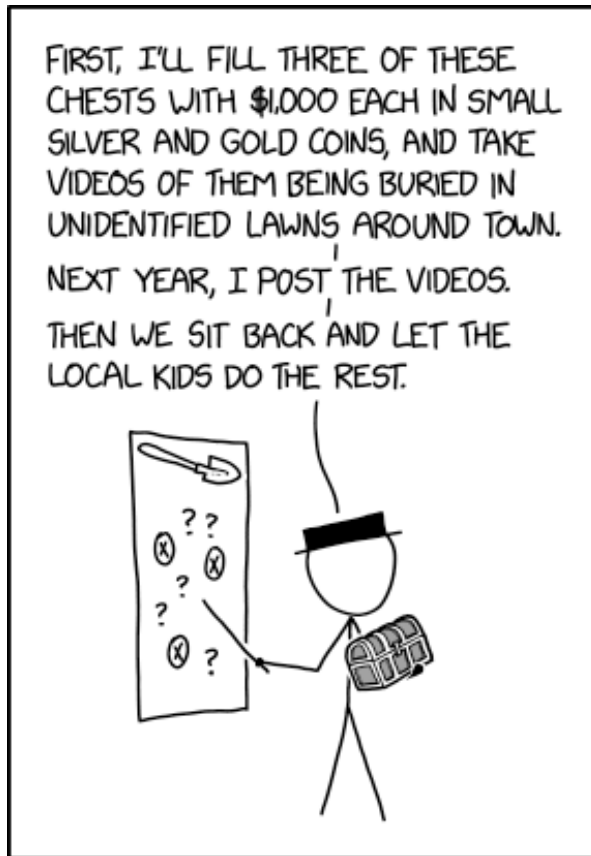
In the title text, he says that his research focuses on "extreme pettiness and unwillingness to let anything go" (in all caps), further reinforcing the reason that he is doing this solely to win an argument. It is possible this is a pun on different meanings of the word "focus" - while the question about the focus of one's research is typically about the subject matter they are researching (raft building in fire ants, etc), Cueball appears to be writing about what drives his desire to do research. Similarly,

Cueball is not doing research INTO pettiness, but rather is focusing entirely on his pettiness as his main reason to perform research and achieve his goals. Of course, there is a focused area of research related to individuals who obsessively pursue matters disproportionately to their severity, who are known as querulants.

It is not uncommon for online forms to include fields like these, where it's unclear what, if anything, will be done with the input, and therefore how much it matters what is entered. It's unlikely that anyone would have the capacity to review all the freetext answers submitted, and in any case, by the time they did so, Cueball would presumably have already accessed the materials he wanted.

#2895: Treasure Chests

February 16, 2024

FIRST, I'LL FILL THREE OF THESE CHESTS WITH $1,000 EACH IN SMALL SILVER AND GOLD COINS, AND TAKE VIDEOS OF THEM BEING BURIED IN UNIDENTIFIED LAWNS AROUND TOWN.

NEXT YEAR, I POST THE VIDEOS.

THEN WE SIT BACK AND LET THE LOCAL KIDS DO THE REST.

THE PROPOSAL FOR CREATING BUSINESS FOR OUR LAWN CARE COMPANY WAS UNORTHODOX BUT *EXTREMELY* EFFECTIVE.

[earlier] "Your vintage-style handmade chest business is struggling. But I have a plan."

Explanation

This comic features Black Hat proposing a way to create significant business for a "lawn care company", for which the comic narrator has an attachment (perhaps owner or employee), albeit in an extremely unethical and possibly illegal manner which is very much congruent with Black Hat's character of being a 'classhole'.

His plan is to create the conditions for a large number of lawns all over a certain town to be dug out by random members of the public, via the motivation of a large potential reward for digging up a lawn (in this case, a chest with $1,000 in the form of silver and gold coins). By filming the burials in such a way that the subsequently posted videos are tantalizingly open to many interpretations as to where they actually were, and then waiting a year to let time obscure any obvious signs of disturbed earth and digging, he encourages feverish speculation among treasure-hunters about the location of the chests, and an incentive to dig up lawns more or less at random, with or without permission.

It is also possible that waiting a year leaves time for one or more chests to have been discovered prior to the 'start' of the deliberate competition to find them. So long as all three weren't (publicly) discovered, it leaves open the possibility that those competing to find the 'unfound' chests will continue with their efforts to find what is now unfindable, prolonging the exercise beyond the point at which all chests could be known to be discovered and

that there are no more chances to gain their riches. Indeed, there is nothing to stop Black Hat from simply digging the chests back up once the videos have been filmed, so that he is not out $3000 and there is nothing to find, prolonging the search indefinitely.

The many homeowners who soon find themselves with ruined lawns would then proceed to contact the lawn care company in order to fix the broken lawns, thus making the business lots of money. For the maximum initial expenditure of $3000 (plus the cost of the containers, and other trivial overheads), a need for significant remediation work will be generated. According to the caption below the panel, the proposal set out by Black Hat turns out to be VERY profitable and EXTREMELY effective. It would be cheaper than most other forms of effective advertisement, such as mass-flyering the catchment area or buying advertising time/space in traditional media, whilst being much more penetrating and focused than any but the most sophisticated (and expensive) forms of online advertising. As long as the 'competition' isn't actually linked to the lawn-care businesss, it also has the advantage that it can create a near maximum potential demand for the service without risking media fatigue and perhaps aversion to the product being advertised. There is no indication that this will be ever be promoted as the company's very own competition, which would probably actively drive the numerous victims of the scheme to find (or found!) rival businesses, not to mention risk the instigation of claims for recompense through civil liability.

The title text shows how Black Hat, before sharing his proposal in this comic, saw a struggling business that made vintage-style handmade chests and cooked up the lawn care plan as a way to boost their sales by generating demand for chests from the lawn company. Sales of three chests doesn't seem a significant uplift for the chest company, which potentially implies that Black Hat has pushed his treasure hunt scheme to multiple lawn care companies, perhaps each in a different town, each buying three chests. One can only speculate about what other companies he may have enticed to take part in this chain of deals, at each point being paid for the pleasure (and keeping the accumulated proceeds), leaving arbitrary amounts of disruption in his wake.

As of the time of posting, silver prices were roughly $23 per ounce / $8 per cm^3, and gold prices were roughly $2000 per ounce / $1250 per cm^3. This means that even the fairly small chest Black Hat has procured, which appears to be around 4 litres, would be very empty if holding $1000 in pure gold or silver coins. Accounting for space between coins, a $1000 chest entirely containing silver coins would be only be filled between 1/8-1/4 liter / 1/2-1 cup, whereas $1000 would only constitute a single medium/large gold coin or a few small ones. However, 'gold' and 'silver' coins may simply refer to higher value coins made either partially from gold and silver, or from some other alloys that give gold and silver colourings. The value might also be based on the face value of gold and silver coins that differ from the market value based on the metal content, or Black Hat might be

using another dollar currency rather than the US dollar. If using U.S. currency, he probably filled it with dollar coins, which currently exist in both gold (the "Sacagawea dollar", the "Native American series", and the "Presidential dollar") and silver (the "American Silver Eagle", the "Susan B. Anthony dollar", the "Morgan" and "Peace" dollars, and the extra-large "Eisenhower dollar") colorations. 1,000 dollar coins would nicely fill a small chest and look impressive enough.

#2896: Crossword Constructors

February 19, 2024

DEAR MS. SWIFT, MR. SHEERAN, MS. MINAJ, MS. GRANDE, AND MR. WEEKND,

WE ARE A GROUP OF CROSSWORD PUZZLE CONSTRUCTORS, AND WE WOULD LIKE TO SUGGEST SOME TITLES FOR YOUR FUTURE ALBUMS:

- AETE
- ENI
- ORETA
- AROE
- OINE
- AEN
- ENTA
- AERAE

Also, we would really appreciate it if you could prominently refer to it as an 'eHit'.

Explanation

This comic is inspired by a common situation when people try to make US-style quick crossword puzzles (where the grid is almost completely filled with words). Here, Cueball, Hairbun, and White Hat are crossword puzzle constructors, but some of the words they would like to use would result in awkward sequences of letters which are not English words or familiar names, such as "aete", "eni", etc. However, they have an idea to write a letter to persuade prominent singers (Taylor Swift, Ed Sheeran, Nicki Minaj, Ariana Grande and The Weeknd) to choose these awkward sequences of letters as titles of their future albums, thereby letting Cueball, Hairbun, and White Hat write clues about those albums and use those letter sequences as answers.

The particular sequences of letters that are selected are notable for their exclusive usage of the most common English letters. Most of them also begin and end with a vowel. These are two features that are common in "crosswordese", i.e., words which appear significantly more often in crosswords than in reality. Examples of crosswordese that are actually used include the words "OREO", "EPEE", and "ONO".

The title text lists another sequence of awkward letters, "eHit". Here, Cueball, Hairbun, and White Hat ask these singers to refer their hits (popular songs) as "eHit"s, adding the "e" for electronic such as in e-mail and e-dating. This is also a reference to common crossword

entries like "E-TAIL" or "E-MAG" which are often criticized for using the prefix "E" to create words that no one really uses.

Possible unintended meanings of words[edit]

- aete: AppleEvent Terminology Extension
- eni: Eni S.p.A., Italian multinational energy company; the name of an England footballer
- oreta: Oreta, moth genus in family Drepanidae
- aroe: Aroe may refer to: The Aru Islands Regency, islands in eastern Indonesia; Aroe, an alternative name for Aroi, Patras, in western Greece
- oine: Kusumoto Ine, also known as O-Ine, Japanese physician; öine means nocturnal/nightly in Estonian, and features in the titles of a number of albums by artists from that country.
- aen: AEN may refer to: Acute esophageal necrosis, a rare esophageal disorder; and more
- Enta da Stage is the debut album by American East Coast hip hop group Black Moon.
- aerae: aerae (Latin noun) genitive/dative singular and nominative plural of aera (era)

The above words and definitions would be considered too obscure for use in most American crossword puzzles, as puzzle editors normally prefer answers to be at least somewhat familiar to the general public, even if the answers wind up being clued obscurely.
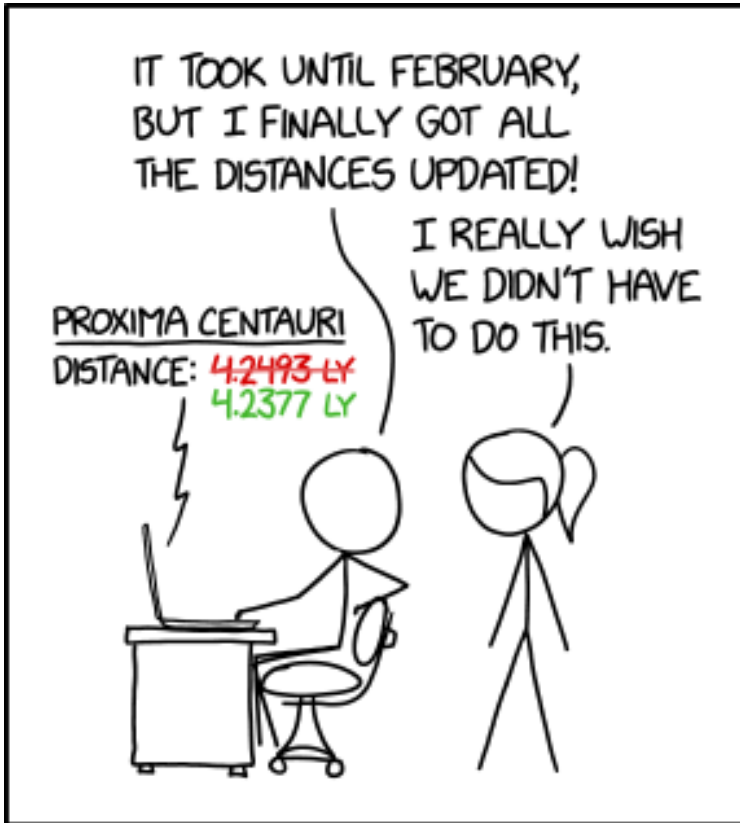
Uses in mainstream crossword puzzles[edit]

Some of these words have appeared in the New York Times crossword, albeit only in the pre-1992 era (that is, before the current editor Will Shortz began his tenure).

- aroe: Clued as a variant spelling for the Aru Islands Regency, and also as part of the phrase "and be thou like unto a roe" from the King James Bible.
- aen: Clued as an abbreviation for the Aeneid or as an abbreviation for the Latin word aeneus meaning "of bronze" or "of copper"

#2897: Light Leap Years

February 21, 2024

IT TOOK UNTIL FEBRUARY, BUT I FINALLY GOT ALL THE DISTANCES UPDATED!

I REALLY WISH WE DIDN'T HAVE TO DO THIS.

PROXIMA CENTAURI
DISTANCE: 4.2493 LY 4.2377 LY

ASTRONOMERS HATE LEAP YEARS BECAUSE THEY MAKE LIGHT-YEARS 0.27% LONGER.

When Pope Gregory XIII briefly shortened the light-year in 1582, it led to navigational chaos and the loss of several Papal starships.

Explanation

The comic features Cueball and Ponytail updating astronomical distances in a database. The caption imagines a world in which leap years, which add an extra day to the year, making it 366 days long instead of 365, purportedly extend light-years by 0.27% due to the additional day (366/365 = 1.0027397...). This adjustment ostensibly reduces the number of light years to celestial bodies like Alpha Centauri by a corresponding percentage — a relatively small amount, but one that corresponds to approximately 730 times the average Earth-sun distance. The comic was released about a week before the leap day of 2024, a leap year.

The joke hinges on the fact that in most common usages years have a variable length, with the Gregorian calendar's leap year system — adding a day every four years to align the calendar year with the astronomical year — being the current civil standard in most of the world. A light year, defined in astronomy as the distance light travels in a vacuum over a Julian year (365.25 days), remains constant at 9,460,730,472,580.8 km, unaffected by the Gregorian calendar's leap years. However, the comic amusingly suggests that leap years lengthen light years, necessitating database updates for astronomical distances.

The title text imaginatively claims Pope Gregory XIII, who introduced the Gregorian calendar in 1582, inadvertently affected the length of the light-year. This is

not due to 1582 being a leap-year (it was not a leap-year), but because of the calendar days that had to be skipped to remove the timing error built up when using the prior (and less correct) Julian method of leap-years. Those adopting the system in 1582 had to shorten this year by ten days. Later adopters may have had to shorten the year that they did change by up to 13 days, i.e. up to three extra days for every four whole centuries spent on the 'wrong' calendar.

A year of effectively 355 days, rather than 365, would therefore lead (by this comic's premise) to potential misunderstandings/misapplications of distance approaching 3%, leading to "navigational chaos" and the loss of "Papal starships." This satirizes the significant historical impact of calendar reforms on navigation and measurement, despite the anachronism, as the light-year wasn't defined until 1838 and the concept of a finite speed of light only emerged in 1676 with Rømer's determination of the speed of light, whilst practical starships (papal or otherwise) that would usefully rely upon light-year measurements, have yet to be developed (on Earth, at least, the only place where such light-year measurements might originate). However, navigational chaos has been a cause of maritime shipwrecks, such as the notable Scilly naval disaster of 1707 in which four ships were lost and over 1,400 sailors died due to navigational errors.

Alternatively, the title text could be interpreted as a joke about how the light-year in astronomy is based on the Julian year (365.25 days) rather than the mean Gregorian

year (365.2425 days). The pope may have briefly changed that definition, leading to "navigational chaos". Although the difference between a Julian light-year and a Gregorian light-year is only about 20 parts per million, it still amounts to about 194 million km (121 million mi) per light year.

This is another comic, after the very recent 2888: US Survey Foot, about how differing interpretations of standard units could have absurd real-world implications. The light-year was previously mentioned in 1047: Approximations.

Discussion of the use of light year values in the comic[edit]
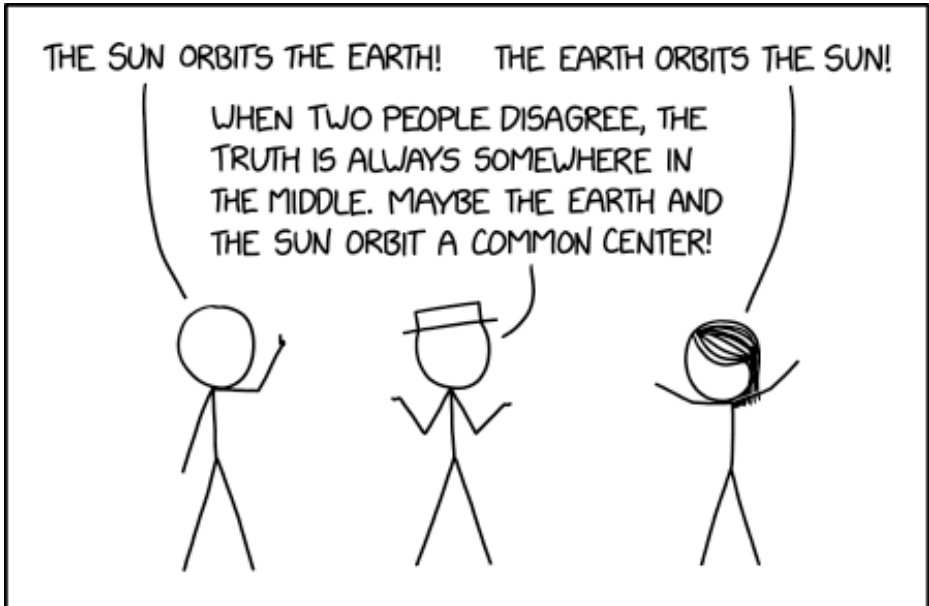
The values given for Proxima Centauri's distance from the Sun, 4.2377 light-leap-years and 4.2493 light-nonleap-years, are consistent with a distance of 4.2464 actual light-years as described by the International Astronomical Union, which is only minutely different from 4.2465 light-years, the value given by Gaia Data Release 3 in 2020. Though tiny on an interstellar scale, the difference between 4.2377 and 4.2493 light-years, 0.0116 light years, equals 109.7 billion km (68.2 billion miles), about 730 times the average distance between the Earth and the sun (150 million km or 93 million miles).

Ironically, this kind of change would not actually bother astronomers in the slightest. Astronomical distances on scales larger than the solar system are universally (or rather, globally: we do not know how things are done in other parts of the universe) measured with the parsec ("pc", or useful multiples such as kpc,

Mpc, or Gpc). One of those is approximately 3.24 light years, so has a similar astronomical magnitude, but is founded upon common interpretations of distance and angle instead of time. (Both partly rely upon baseline measures that are complementary aspects of Earth's orbit, i.e. its periodicity and radius, which theoretically make for a globally agreeable system; but highly unlikely to match whatever equivalent any non-terran scientists would independently develop.) While light-years, and related units, are common in publications intended for non-astrophysicists and for the benefit of laypersons, they are generally considered as secondary usefulness to parsecs within the actual fields of astronomy and astrophysics research. As such, it is highly likely that the clearly exacting database that Cueball and Ponytail are in the process of modifying is not even keyed to any light-units, making leap-/non-leap-light-years already an automatic conversion that the system may pander for without such a direct interaction.

#2898: Orbital Argument

February 23, 2024

THE SUN ORBITS THE EARTH!

THE EARTH ORBITS THE SUN!

WHEN TWO PEOPLE DISAGREE, THE TRUTH IS ALWAYS SOMEWHERE IN THE MIDDLE. MAYBE THE EARTH AND THE SUN ORBIT A COMMON CENTER!

IT'S ANNOYING WHEN PEOPLE ARE RIGHT BY ACCIDENT.

"Some people say light is waves, and some say it's particles, so I bet light is some in-between thing that's both wave and particle depending on how you look at it. Am I right?" "YES, BUT YOU SHOULDN'T BE!"

Explanation

In this comic, White Hat is using the middle ground fallacy to try to make a compromise between the positions of Cueball and Megan.

Cueball appears to be asserting a geocentric viewpoint, whilst Megan adheres to a heliocentric one, both of which are flawed descriptions of the way things are, but the latter is much closer to reality. White Hat, however, considers it politic to 'split the difference' and declares his intention to compromise with a 'middle' option, to try to uncritically please both parties. (Though it's probable that he may instead just equally annoy them both!)

On a naive reading, which imagines a point of common orbit midway between the bodies, his thesis is simply wrong. However, by one way of looking at it, it happens that he is also correct. Because two bodies exert equal but opposite gravitational forces on each other, each orbits around the average location of the other, and therefore they both orbit a common center. This barycenter is located somewhere between the centers of mass of the two bodies; the distance of each body's center of mass from the barycenter is proportional to the other body's mass. This is most apparent in systems where the two bodies have similar masses, but it is present to an extent in all orbital pairs, even when one body is far more massive than the other. For this reason, Earth does not orbit the center of the stationary Sun as described by the heliocentric model. However, the Earth-Sun barycenter

is only slightly different from the Sun's own true center, still well within the Sun. It is around this which the Sun wobbles (ignoring the effects of the other planets; Jupiter actually has the largest effect on the Sun), in contrast to the way the Earth orbits around this unequally proportioned midpoint.

That White Hat has worded his compromise solution in a way that (arguably) encompasses the deeper truth of the barycentric viewpoint is not treated as justifying his mediating approach. It is clearly understood, by someone who seems to understand the complexities (e.g. a NASA physicist) that White Hat's 'successful' conclusion is just accidental, and such a person may therefore find this vexatious. This seems to be a case of a Gettier problem: White Hat reaches a true statement via unjustified logic.

The title text extends the principle of the comic's astronomical viewpoint down to the correspondingly opposing 'quantum world'. For various well-studied reasons, light is often described either as particles or as waves. White Hat's approach would be to give both viewpoints equal credit and suggest a compromising middle-ground explanation. In this case, also, he would have the correct answer but, in the continuing view of an increasingly exasperated witness to his chronic "half-and-half"ism, not through a logical proof. Averaging predictions of experts is used to reliably improve the accuracy of the ensemble, as well as other methods that might produce a consensus forecast, so his heuristic may indeed have some validity for some types of prediction along a continuum of possibilities. But, for

this case, two opposing philosophical positions do not represent the right kind of data to merge into a balanced 'best fit' intermediate predictive model.

Another example of the middle ground fallacy was used in 690: Semicontrolled Demolition, although in that case the person offering the compromise solution was not portrayed as getting the right answer by accident.

Orbits of celestial bodies are quantified using a set of parameters called orbital elements. Some of these parameters are commonly known as arguments, such as the Argument of periapsis. However, these kind of arguments tend to lead to consensus rather than disagreements. Independent measurements of the arguments might indeed be combined by taking the mean (to discover the middle ground).

The Earth-Moon barycenter is located approximately ¾ of the way from Earth's center of mass to its surface, towards the Moon's center of mass. The equivalent Jupiter-Sun barycenter, meanwhile, is located just above the 'surface' of the Sun due to the masses involved being not as different (but still significantly so), and the much greater distance between them. Pluto-Charon barycenter is located completely outside of Pluto, in part because they are much more similar masses, and are thus considered to orbit each other (tidally locked) around a point approximately 5.4% along the distance between the surfaces of Pluto surface and Charon, or 11% of their center-to-center distance.

As each of the planets and the Sun are simultaneously orbiting/"being orbited" (and every planet also measurably pulls on every other, etc, even discounting every smaller and/or more distant body in the universe), the combined solar-system's barycenter is a less simply-defined point (that being more likely to be within the Sun, at any given point of time), which can often be considered to more simply average out to "<each planet> orbits the Sun" for most purposes.

February 26, 2024

WHEN A METRIC BECOMES A TARGET, IT CEASES TO BE A GOOD METRIC.

SOUNDS BAD. LET'S OFFER A BONUS TO ANYONE WHO IDENTIFIES A METRIC THAT HAS BECOME A TARGET.
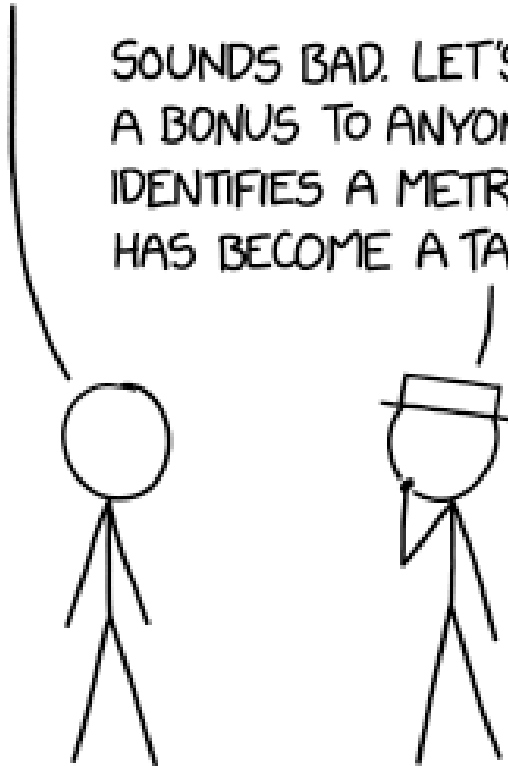
[later] I'm pleased to report we're now identifying and replacing hundreds of outdated metrics per hour.

Explanation

In this comic, White Hat suggests creating a meta-metric, "number-of-metrics-that-have-become-targets," and making it a target.

First, Cueball introduces and defines Goodhart's Law, which is the observation that when a metric — a measure of performance — becomes a goal, efforts will be unhelpfully directed to improving that metric at the expense of systemic objectives.

For example, imagine a scenario in which a car dealership is looking to grow profits, and its managers decide to focus on increasing a component metric of profit: how many cars it sells. So they offer a bonus to their salespeople to sell more cars. But then the salespeople offer deep discounts to rack up sales, rendering the car sales unprofitable. This example shows how a metric (cars sold) can become the target, replacing the real target, profit growth, if individual incentives are not properly managed.

Hearing about Goodhart's Law, White Hat suggests eliminating metrics that have become targets.

White Hat's suggestion could be a good or a bad idea. It all depends on how the bonus incentive is awarded:

• A well-designed implementation would award bonuses only for finding metrics which truly aren't serving their purpose, so the organization's managers could fix the

measurement issues (assuming the fix isn't worse than the status quo), and would employ sufficient management oversight to discourage trivial submissions. If submissions are in good faith, bonuses are awarded only for approved submissions, and the identifications result in real improvements, the organization will likely be better off.

- A poorly-designed implementation would offer a bonus to every identification, regardless of quality. This would incentivize the identification of even quite useful metrics — and perhaps even the creation of new metrics-as-targets for the sole purpose of then removing them and collecting the bounty.

The title text imagines this poorly-designed implementation, leading to the creation of a new metric (metric changes per hour) and the organization identifying — and replacing — hundreds of metrics per hour, crowding out actual focus on the organization's true goals. It's the ultimate example of "change for change's sake."

Part of the joke is that White Hat's original suggestion — the new metric causing the issue and one that should be replaced — seems to be ironically surviving the replacement of hundreds of other metrics.

This comic illustrates that the thoughtless combination of Goodhart's Law and poorly designed incentives can have ruinous results for an organization.

The proper usage of organizational metrics and

incentives is the focus of managerial accounting, a field within organizational management.

Discussion of the promises and perils of operational measurement[edit]

While there is a temptation to game any metric, measurement is the main objective way of describing the success of an activity and assessing the effect of changes. "Data-driven" or "evidence-based" approaches are used to drive measurable improvements in various areas of society.

Discussions of Goodhart's Law have noted that people may respond to a metric by either (1) improving the system, (2) distorting that system (examples below), or (3) distorting the data (e.g., governments publishing false or cherry-picked economic data). Channeling energy toward improvement requires an organization to make (1) more appealing (flexibility and culture) and the others less (transparency, culture, reduced pressure to meet unrealistic goals). Figuring out how to do that involves a slow and thoughtful process unlike White Hat's kneejerk jump to a new metric.

## Additional examples of Goodhart's Law[edit]

- The classical example of Goodhart's Law is the Cobra Effect: anecdotally the British rule in India paid bounties for dead cobras as a pest control effort. People quickly realized that more cobras allowed them to harvest more for the bounty, and began actively breeding cobras.
- School test scores are intended as a metric for how well a school is teaching its students. When that becomes an incentivized target, schools are forced to design their curriculum around the

exams, which can create a more rigid system which fails to engage students and teachers. In extreme cases, this can motivate decisions to remove underperforming students from school districts, or encourage teachers to allow or even facilitate cheating.

- A hospital measures inpatient Length of Stay because shorter stays save money and free up beds for other patients. But this metric, on its own, may encourage doctors to discharge patients too soon. This not only puts patients at risk, but can also result in costly re-admissions.

- A call center measures the number of calls handled per hour as a measure of worker productivity. This can drive workers to rush through calls, terminating them as quickly as possible, which can lead to short, frustrating interactions.

- The hypothetical Paperclip Maximizer concept demonstrates how having a seemingly benign metric as a goal might still result in almost unlimited adverse effects, if unchecked.

#2900: Call My Cell

February 28, 2024
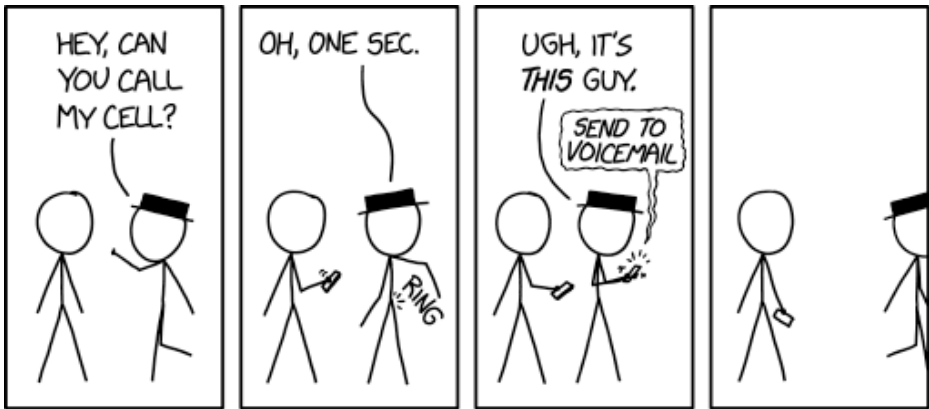
'Hey, can you call my cell?' '...I'm trying, but it says this number is blocked?' 'Ok, thanks, just checking.'

Explanation

When a person cannot find their cell phone, it is not uncommon to ask a friend to call the phone in question. This will activate the device's ring tone and/or vibration mode, assuming the device is not off or silenced, making it easier to find (this is also one of the meanings of "xkcd").

At first, Black Hat appears to have misplaced his cell phone, as he asks Cueball to call it. However, when Cueball does call Black Hat's cell, it is revealed to be in Black Hat's (supposed) pocket. He then makes a show of annoyance that Cueball ("this guy") is calling him, sends the call to voicemail, and leaves. From this, it might be inferred that Black Hat was simply trying to demonstrate that he doesn't want Cueball to call him, showing another of his classhole tendencies, as Black Hat is quite often depicted as deliberately inconsiderate and rarely prone to actual carelessness.
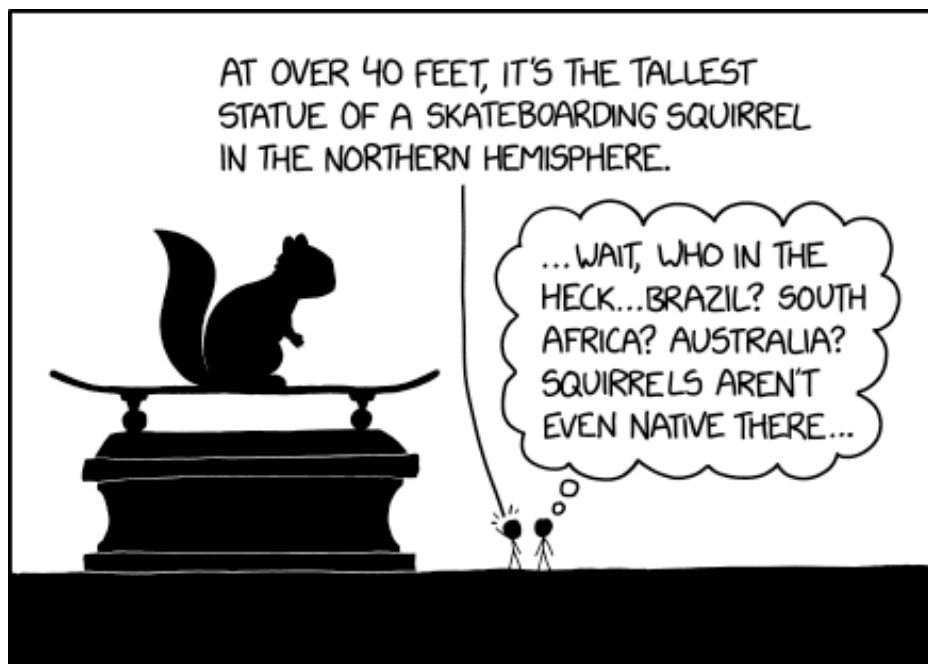
The title text is a similar situation. Cueball calls Black Hat, but instead Black Hat demonstrates that he was only "checking" that he had blocked Cueball's number so Cueball is unable to reach his cell, making an even stronger insult. This can also be seen as a grammatical accuracy. When Black Hat asks "Can you call my cell?" he is asking whether Cueball is able to place a call on Black Hat's cell phone. This would be a variation of a particularly pedantic authority figure replying to a "Can I...?" question with the response like "I imagine you can,

but (right now) you may not..." and so denying the request. In this case, the answer to the strict interpretation would have been "No", rendering the implied issue of permission entirely moot.

This comic may be related to 1284: Improved Keyboard, where Black Hat stops Cueball from texting him by changing his keyboard.

#2901: Geographic Qualifiers

March 01, 2024

AT OVER 40 FEET, IT'S THE TALLEST STATUE OF A SKATEBOARDING SQUIRREL IN THE NORTHERN HEMISPHERE.

...WAIT, WHO IN THE HECK...BRAZIL? SOUTH AFRICA? AUSTRALIA? SQUIRRELS AREN'T EVEN NATIVE THERE...

I LOVE THE INSTANT MYSTERY CREATED BY QUALIFIERS LIKE "EAST OF THE MISSISSIPPI" OR "IN THE NORTHERN HEMISPHERE."

'Thank you for the loveliest evening I've ever had...' [normal] '...east of the Mississippi.' [instant intrigue!]

Explanation

In this comic, Cueball is bragging to a Cueball-like guy in front of a giant statue of a squirrel standing on a skateboard. Cueball states that this is the largest statue of that theme in "the Northern Hemisphere". The other guy then becomes intrigued, as he realizes that this seems to imply the existence of a taller one in the Southern Hemisphere, not to mention the existence of additional smaller one(s) in the Northern Hemisphere. A skateboarding squirrel is a peculiar enough subject that to find one example of such a statue would be a surprise, and to learn that there is at least one other would be even more surprising.

He quickly considers several countries in that hemisphere, Brazil, South Africa, and Australia. Native squirrel species are found in both Brazil and South Africa, and people there might plausibly choose to erect statues to them. Australia, however, has no native squirrels, and introduced populations of gray and palm squirrels reportedly have been eradicated, at considerable expense of time and money. "Confused Cueball" wonders whether Australians would know or care enough about squirrels to erect statues to them. It so happens, though, that many animals (and many entirely fictional ones) are depicted as statues in countries where they are not native, Australia is known for its many overly large statues, and 1.5 m (5 foot) tall squirrel statues are already sold there. So the existence of squirrel statues in the Southern Hemisphere that are larger than the one

Cueball is bragging about is not out of the question - but the comic doesn't permit "confused Cueball" the half hour he'd need to drag out his phone and look up all these facts. The question about whether, and how many, of these putative squirrel statues are mounted on a skateboard is separate, although there is nothing in the urban cultures of the places named to preclude this possibility.

It's entirely possible that this qualifier is unnecessary. If the statue were the largest of its kind in the world, or even the only one in the world (which is a distinct possibility, given the very specific nature of the statue), the description would still be true. Sometimes qualifiers are added simply due to incomplete information. They've exhaustively surveyed skateboarding squirrel statues in the Northern Hemisphere and determined that this one is the largest, but since they haven't searched the Southern Hemisphere, they don't want to commit to it being the largest in the world. On the other hand, it's possible that, paradoxically, he deliberately added a needless qualifier in an attempt to make the claim sound more impressive, even though technically it limits its scope, by implying intense competition for a title that, in reality, no one else is interested in claiming. Randall states, in the caption, that he loves the mystery that such qualifiers create. Doing so could thus have been one of Randall's hobbies, but he doesn't make that explicit.

Another example appears in the title text, where Randall uses the other example qualifier given in the caption. Here someone is expressing gratitude at the end of a date,

saying that it's the loveliest evening they've ever had. This seems normal until they add the location qualifier of "east of the Mississippi" (the river). This leaves the companion wondering what kind of great evening they had in some other location. In this case, it's unlikely that the speaker would have incomplete information about their own personal history.

The statue may be a reference to Ms. Pearl, the giant squirrel statue in Cedar Creek, Texas which, at 14 ft (4 m), is indeed the largest squirrel statue in the Western Hemisphere. In 2018, the qualifier was necessary since a 40 ft (12 m) squirrel statue was erected in Kazakhstan. (It is no longer there.) But information for tourists in Cedar Creek, Texas, doesn't include this information that would create the mystique.[actual citation needed]

It is perhaps thanks only to the specific phrasing "tallest statue of a skateboarding squirrel" that we need not consider tallest-statues-of-squirrels (temporarily) placed on skateboards, tallest statuesque skateboards with squirrels atop or even a rather modestly sized statuette representing a moment when a large skateboard had sciurine visitors, in any or all hemispheres.

In 1368: One Of The, the use of the unnecessary qualifier "one of the" was portrayed as one of Randall's Pet Peeves, with a reporter describing the Gateway Arch as "one of the most recognizable arches in St. Louis", when it could have been described as "the most recognizable arch" in the city.

#2902: Ice Core
March 04, 2024

NEXT, WE'LL IDENTIFY THE ICE CORE LAYER MATCHING YOUR BIRTH YEAR. DO YOU HAVE THE SHAKER READY?

MAKING THE TRADITIONAL PALEOCLIMATOLOGIST COCKTAIL

If you find an ash deposition layer from a year in which an eruption destroyed an island that had Camellia sinensis growing on it, you can make a Gone Island Ice_.
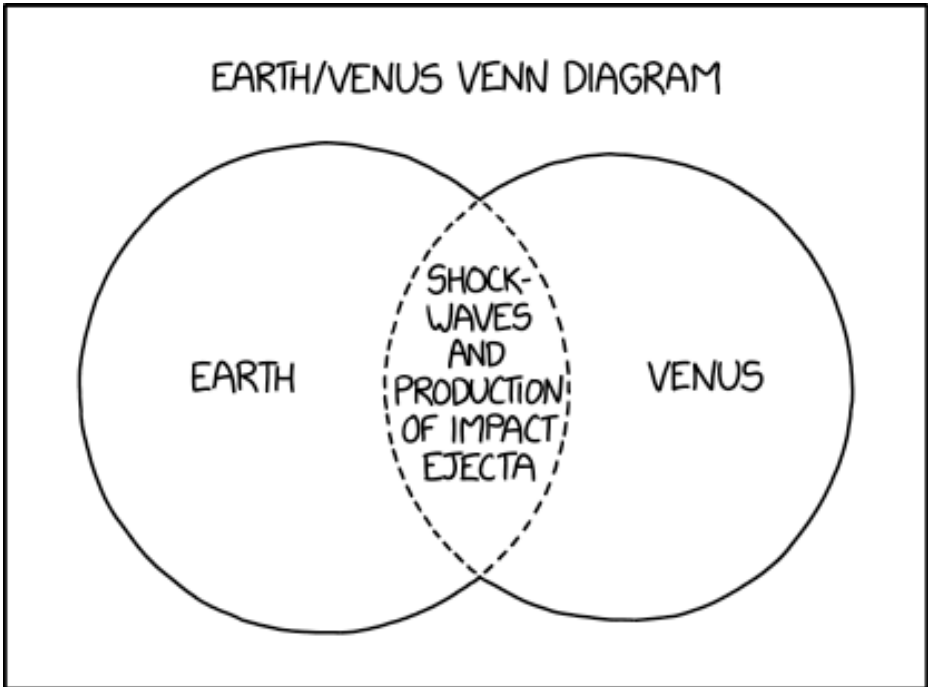
Explanation

Some people may like to taste a wine dated to the year they were born, or perhaps are subject to it as a family tradition. This would more typically be for a special occasion such as a milestone birthday than because it happens to be a 'good year' for the wine(s) they favor (unless they were particularly fortunate). Reaching the legal drinking age would be an appropriate opportunity to partake in a wine that is the same age as themselves. This comic extends this practice into a joke that paleoclimatologists, who study the climate, use dated ice instead of dated wine, drilling into the ground to find the layer of ice matching the birth year of the recipient, either to drink 'neat' (once sufficiently melted) or as the 'on the rocks' part of another drink, perhaps a cocktail.

Megan, a paleoclimatologist, decides to make a cocktail with the ice from the ice sheets (present in the Arctic and Antarctic, for example). Normally, scientists would try to date the ice and then use it to describe the state of the climate when these ice sheets formed. Here, Megan tries to find the ice layer corresponding to Knit Cap's birth year to use the ice for the chosen drink. The caption asserts that this method of creating drinks is "traditional" for paleoclimatologists. She then asks if Knit Cap has the cocktail shaker that they presumably brought to the site ready. Cocktail shakers are used in the preparation of many mixed drinks, which often contain ice (usually produced by refrigeration, rather than harvested from natural sources).

The title text says that if they manage to find some ice with ash coming from an eruption which destroyed an island with Camellia sinensis growing on it, they'll be able to make a cocktail called a 'Gone Island Ice_τ', which is a punning reference to the cocktail known as a Long Island iced tea. Camellia sinensis (common name, "tea plant") is generally used for making tea, so this cocktail would have tea infused into the ice. The Greek letter tau is used in place of "tea". The joke here likely is that this character is used in various fields to denote time, and presumably in this case refers to the time the ice deposit in question dates to.

#2903: Earth/Venus Venn Diagram

March 06, 2024

EARTH/VENUS VENN DIAGRAM

EARTH — SHOCK-WAVES AND PRODUCTION OF IMPACT EJECTA — VENUS

Actually, the fact that Mars is still orbiting safely over here means that it was technically an *Euler* apocalypse, not a Venn one.

Explanation

A Venn diagram illustrates the relationships and differences among sets by showing common and distinct elements, using overlapping circles (or other shapes). This comic is both a Venn diagram and a proximity illustration of Earth and Venus colliding, physically 'overlapping' each other.

- As a proximity illustration, it depicts Earth and Venus smashing into each other, resulting in "shockwaves and production of impact ejecta" occurring where they collide. The relative circle sizes are accurate; the circumference of Venus is 5% smaller than Earth's.
- As a Venn diagram, it shows a collision moment in which the commonality between Earth and Venus is "shockwaves and production of impact ejecta" at the spot of intermingled Earth-Venus overlap.

Shockwaves are intense, high-pressure waves caused by the immense force of the impact, that propagate through the materials of both planets faster than the speed of sound.
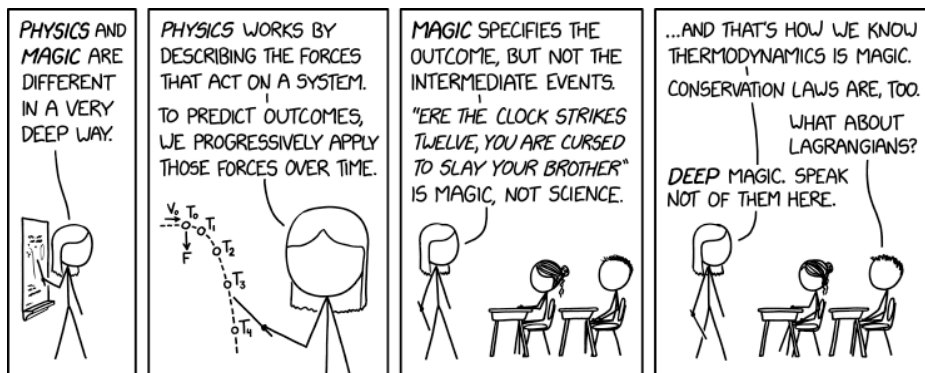
Impact ejecta are the materials expelled from the impact site, consisting of molten rock, vaporized material, and solid debris, flung out at high velocities due to the energy released by the collision. The production of impact ejecta would indeed occur in the overlapping impact area.

The title text is another xkcd joke about the difference

between a Venn diagram and an Euler diagram, which is similar to a Venn diagram except that it's acceptable to have circles (or other shapes) that do not intersect if there are no common elements between those sets. The observation that Mars is still orbiting by itself makes Mars an additional set (out of the frame of the diagram), in addition to - but not intersecting with - Earth and Venus, making this technically an Euler diagram. Therefore if the Earth-Venus collision is a "Venn apocalypse," the inclusion of Mars as a non-intersecting entity makes this technically an "Euler apocalypse."

#2904: Physics vs. Magic

March 08, 2024

Panel 1: PHYSICS AND MAGIC ARE DIFFERENT IN A VERY DEEP WAY.

Panel 2: PHYSICS WORKS BY DESCRIBING THE FORCES THAT ACT ON A SYSTEM. TO PREDICT OUTCOMES, WE PROGRESSIVELY APPLY THOSE FORCES OVER TIME.

Panel 3: MAGIC SPECIFIES THE OUTCOME, BUT NOT THE INTERMEDIATE EVENTS. "ERE THE CLOCK STRIKES TWELVE, YOU ARE CURSED TO SLAY YOUR BROTHER" IS MAGIC, NOT SCIENCE.

Panel 4: ...AND THAT'S HOW WE KNOW THERMODYNAMICS IS MAGIC. CONSERVATION LAWS ARE, TOO. WHAT ABOUT LAGRANGIANS? DEEP MAGIC. SPEAK NOT OF THEM HERE.

'At the stroke of midnight, your brother will be hurtling sideways at an altitude of 150 meters' is a regular physics prediction about your nonmagical trebuchet, whereas 'you are cursed to build a brother-launching trebuchet' falls out of the Lagrangian.

Explanation

This comic explores the distinctions between magic and physics through the perspective of Miss Lenhart, a schoolteacher. She explains that physics involves the continuous application of forces to objects over time, whereas magic reveals the outcome without detailing the process. She illustrates her point with a magical curse example that dictates the recipient will slay their brother by midnight (or possibly noon), highlighting its lack of scientific basis due to the absence of a causal explanation. She further contends that the laws of thermodynamics, among other laws, fall into the category of magic, with Lagrangians representing a deeper level of magic.

The humor in this comic arises from the observation that foundational physical laws, despite being empirically derived, lack explanations for their inherent truths. According to the logic presented in the second panel, these laws resemble magic as they specify outcomes without clarifying the means to achieve them. While some laws might be derived from others, ultimately, we accept certain principles as given, akin to magical reasoning.

The second panel references Newtonian mechanics, depicted as an initial value problem, which establishes a system's initial conditions and its temporal evolution based on specific rules. This formulation aligns with our intuitive understanding that the present is a known state and the immediate future is determined by present

conditions. The final panel humorously juxtaposes this notion with various physics concepts that challenge our basic assumptions in progressively disconcerting ways.

Specifically, equilibrium thermodynamics, a major branch of thermodynamics familiar to students, makes predictions about a system's eventual state without accounting for its current state or intermediate behaviors. This perspective seemingly contradicts the principle introduced in the first panel, although the concept of inquiring about long-term stability without detailed process knowledge remains intuitively accessible.

Conservation laws, emerging naturally from Newtonian physics, present another conceptual challenge. While basic explanations involve calculus and elementary algebra, more advanced interpretations connect conservation laws to physical system symmetries in a highly abstract and enigmatic manner. These laws, therefore, make permanent statements about a system's state, independent of its evolution, challenging the initial principle in a manner that feels even more counterintuitive than thermodynamics. Notably, particle physics conservation laws, except in cases involving the weak nuclear force, maintain certain system properties like charge, spin, and parity.

Lagrangian mechanics, a reinterpretation of classical physics equivalent to Newton's laws, diverges by considering both initial and final states to determine physically permissible trajectories. This approach directly opposes the first panel's principle, mirroring the magical

definition by surprisingly and counterintuitively aligning the intuitive Newtonian perspective with the "magical" frameworks of Lagrangian and Hamiltonian mechanics. Therefore, the comic labels Lagrangians, central to Lagrangian mechanics and system dynamics description, as 'Deep Magic', highlighting their role in encapsulating physics' magical aspect.

Furthermore, the comic might hint at the teleological debate within physics, especially regarding the stationary-action principle's potential teleological interpretations. This principle, foundational to deriving various equations of motion across physics fields, suggests a teleological element by inferring initial conditions from specified final conditions, challenging the conventional causality narrative.

The title text merges the comic's thematic elements, contrasting a nonmagical trebuchet prediction with the mystical implications of the curse, further blending the lines between physics predictions and magical foresight.

#2905: Supergroup

March 11, 2024

PLAYING TONIGHT
THE NEW SUPERGROUP:
176 PILOTS, SECONDS OF SUMMER, NON BLONDES, LIVE CREW, GECS, DOORS DOWN, INCH NAILS, REPUBLIC, DIRECTION, AND SECONDS TO MARS

I love their cover of 1,200 Balloons, Dalmatians, and Miles.

Explanation

In popular music, a supergroup is a musical group formed by collaboration of existing solo artists and members of other musical groups.

This comic shows a marquee announcing a concert by a supergroup formed from members of 10 musical groups whose names all begin with a number. The name of the supergroup is the sum of all those numbers, 176, followed by the names of the original groups without their numbers. It's reasonable to estimate that there could be up to 32 members of the supergroup (see below).

Musical groups mentioned in the comic:

- Twenty One Pilots
- 5 Seconds of Summer
- 4 Non Blondes
- 2 Live Crew
- 100 gecs
- 3 Doors Down
- Nine Inch Nails
- OneRepublic
- One Direction
- Thirty Seconds to Mars

Sum: $21 + 5 + 4 + 2 + 100 + 3 + 9 + 1 + 1 + 30 = 176$

It should be noted that this summation, taken literally, is mathematically wrong, as it not only adds numbers with different units and dimensionality (eg, pilots are not the same dimensionality as seconds), but one of the summands (3 in 3 Doors Down) is an ordinal number and another (9 in Nine Inch Nails) is part of an adjective phrase, which is analogous to saying that four metres and one metre cubed add up to seven metres.

The title text indicates that this supergroup performs a medley or mashup of songs whose titles begin with numbers. The title of this "supersong" is similarly formed by adding the numbers and following with the rest of all the titles. Notably, none of the referenced songs were written by any of the referenced artists.

Songs mentioned in the title text:

- 99 Luftballons (by Nena). 99 Red Balloons is the title of the English-language adaptation of the song.
- One Hundred and One Dalmatians (Disney film soundtrack). The titular song by the Sherman Brothers is not featured in the film, but was released in separate Disney recordings.
- A Thousand Miles (by Vanessa Carlton). Other songs titled "1000 Miles" or "Thousand Miles" also exist.

Sum: 99 + 101 + 1000 = 1200

"I'm Gonna Be (500 Miles)" by the Proclaimers is about walking "500 miles, and [...] 500 more", therefore a thousand miles in total. There are two more songs titled

(or known as) "500 Miles", by Hedy West and Tori Amos, which could be added up to replace "A Thousand Miles" (or "1000 Miles") in the tally as well.

The supergroup could have 32 members:

- Twenty One Pilots: This band has 2 members, Tyler Joseph and Josh Dun.
- 5 Seconds of Summer: There are 4 members in this band, including Luke Hemmings, Michael Clifford, Calum Hood, and Ashton Irwin.
- 4 Non Blondes: Originally, this group had 4 members, but it disbanded in 1994. The lead singer was Linda Perry.
- 2 Live Crew: This group's core lineup included 2 to 4 members over different periods, with notable members being Luther Campbell, Brother Marquis, Fresh Kid Ice, and Mr. Mixx.
- 100 gecs: This band consists of 2 members, Laura Les and Dylan Brady.
- 3 Doors Down: This band typically has 5 members, although the number has varied with lineup changes over the years.
- Nine Inch Nails: Officially, Trent Reznor and Atticus Ross are the only constant members of Nine Inch Nails, with a changing lineup of touring members and collaborators.
- OneRepublic: This band has 5 members, including Ryan Tedder, Zach Filkins, Drew Brown, Brent Kutzle,

and Eddie Fisher.

- One Direction: Originally, there were 5 members in this band, but after Zayn Malik's departure in 2015, it continued with 4 members until their hiatus.

- Thirty Seconds to Mars: This band has had various lineups but is centered around Jared Leto and Shannon Leto, with other members joining and leaving at different times.

Sum: $2 + 4 + 4 + 2 + 2 + 5 + 2 + 5 + 4 + 2 = 32$

These counts mostly reflect the bands' most well-known lineups and may vary with time due to changes in membership or the band's status. Combined groups may feature fewer than the sum of their original memberships, even down to just single musicians/vocalists coming from any or all of their prior collaborations. On the other hand, especially for worthy causes, it is possible that groups with many changing lineups could perhaps rustle up far more members than they ever had at a given time, never mind any prominent artists who may guest-star in their own right. It is unclear whether the band names would be pro rated in these circumstances (for example, if only one of 100 gecs joined the supergroup, would they only count for 50?).

Potential connection to mathematical supergroups[edit]

Randall may be making a subtle reference to mathematical physics, in which a supergroup is a generalization of a group based on the concept of supersymmetry.
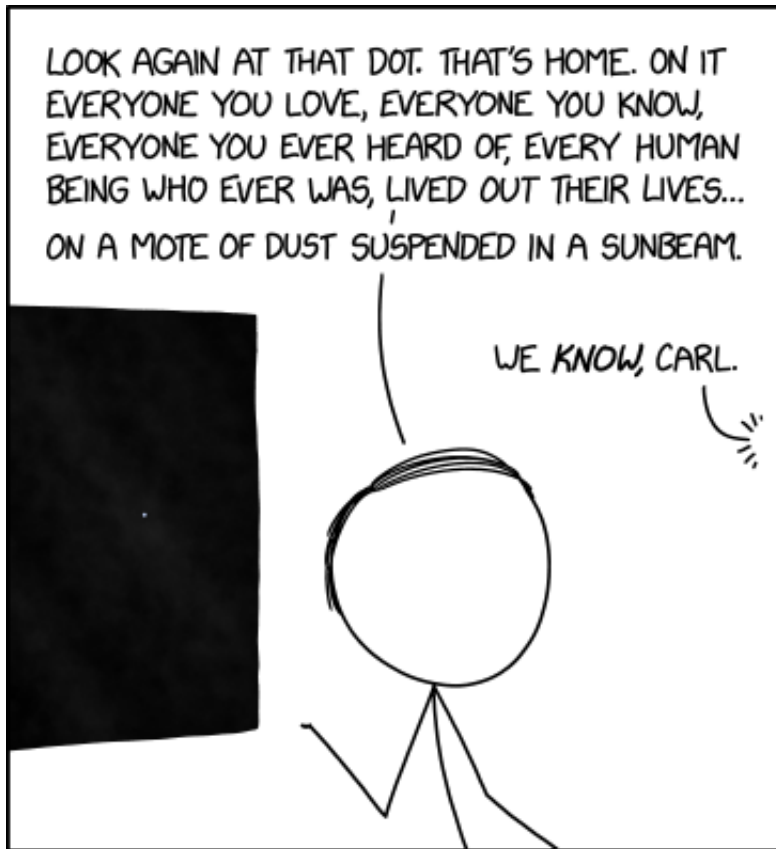
Readers with a background in mathematics or physics might find their expectations thwarted upon realizing that the comic is about mundane musical collaborations. But then, "every supergroup carries a natural group structure, but there may be more than one way to structure a given group as a supergroup", which applies to both contexts.

Miscellaneous numeric observations[edit]

100 gecs provides the most "bandname per member" (100 / 2 = 50), with OneRepublic and One Direction each vying for most "members per bandname" (both 5, at their most complete). Counting the songname mashup ratios is more complex: if it is not a single "1000 miles", perhaps the two Proclaimers can be said to be each singing 500 miles, to match the other solo artists' alternate 500s (depending upon which source(s) are chosen as canon), but a single luftballon requires just slightly over 1% of Nena (whether the eponymous singer or shared throughout her band of five) and a lone Dalmatian slightly less than 1% split amongst an uncertain number of originators.

#2906: Earth

March 13, 2024

LOOK AGAIN AT THAT DOT. THAT'S HOME. ON IT EVERYONE YOU LOVE, EVERYONE YOU KNOW, EVERYONE YOU EVER HEARD OF, EVERY HUMAN BEING WHO EVER WAS, LIVED OUT THEIR LIVES...

ON A MOTE OF DUST SUSPENDED IN A SUNBEAM.

WE *KNOW*, CARL.

CARL SAGAN WAS *NOT* MAKING US FEEL BETTER ABOUT HOW BADLY HE'D MESSED UP THE LOW EARTH ORBIT REENTRY BURN.

Just think of all the countless petty squabbles and misunderstandings, of all the fervent hatreds, over so insignificant a thing as the direction and duration of a rocket engine firing.

Explanation

At first sight, this appears to be the famous Carl Sagan commentary, upon the Pale Blue Dot image of Earth, a picture taken by the Voyager 1 probe in 1990 (at that time 6 billion kilometers away) but having been transmitted back to Earth to be appreciated as one of the most iconic 'photos of Earth from space', along with Earthrise and The Blue Marble. Sagan's written, and later spoken, words evoke how the lives of all of us are somehow confined to barely more than a single pixel's-worth of existence upon an already zoomed-in view of space.

From the caption, however, it appears that 'Carl' is not looking at an image. Instead it is a spacecraft window. The minute apparent size of the Earth is as a result of the spacecraft being very far from Earth. This is an unintended consequence of an attempt to deorbit from low Earth orbit (i.e. not more than 2000 kilometers from the Earth's surface, from which the Earth should still mostly fill any view that points towards it). Rather than transitioning from LEO into a re-entry trajectory, somehow the vessel and crew have been sent into a much higher-reaching orbit, if not into a solar or extra-solar trajectory. And it is apparently Carl's fault. The speech is thus not an inward view of where we all are, but an outward look at somewhere that all the crew (unwillingly, and against all recent expectations) are not.

The title text continues with the traditional tone of the

speech, only to become an implicit attempt to claim that it wasn't quite as drastic an error as it actually seems to have been.

The very same words (or as far as they go), but in the more traditional situation of an informative lecture, were previously used in 1246: Pale Blue Dot.

The scale of the error[edit]

The comic's distance from Earth is unlikely to be anywhere near that of Voyager 1, and would not be being seen portrayed by the same 1500mm high-resolution narrow-angle camera as took the alluded-to image. The apparent size of Earth, compared with Carl at his window, would depend a lot on the actual 'camera' geometry/position for the scene. For comparison, however, the Earth seen from the Moon is slightly under four times the diameter of the Moon as seen from the Earth, or perhaps nearly the size of a clenched fist, held at arm's length. This implies (unless the scene uses a particularly wide-angled lens, close to Carl and the window) that the vessel's position is now significantly beyond the orbit of the Moon.

The absence of a clearly visible Moon, which would have a near-identical phase to the illuminated Earth and could easily be the second brightest object in the scene, is therefore best explained by it being no more than a sub-pixel object, indistinguishable from the surrounding darkness of space, somewhere within thirty Earth diameters (and thus approximately, in this image, pixels) of the visible Earth. This could include being sufficiently in conjunction/opposition to Earth to blend in, or be obscured by it.

The general lack of other visible stars, etc, would be explained by the exposure being tuned to not wash out the illuminated internal view, and not being set up for useful astronomical shots, though may then set another range of useful limits on what magnitude of reflected sunlight must still arrive from Earth in order to remain visible.

The orbital speed in low-earth orbit is ~8 km/s. A typical de-orbiting maneuver requires slowing down by about 100 m/s (which according to the What If chapter "Orbital Submarine" could be accomplished with the 24 Trident missiles carried aboard an Ohio-class submarine.) However, escape speed is ~11 km/s, meaning the vessel must go faster by ~3 km/s. So Carl has indeed made quite an error if he fired the boosters thirtyfold too much and in the opposite direction (or 190fold in the correct direction, resulting in the spacecraft traveling in the opposite direction of previously).

The "pale blue" dot[edit]

Although it might initially look like a white dot, the comic truly has used a pale blue color for the dot that represents Earth, with the color used in the "2x" version of the image seeming to be 0xBDCFF4.

This can be interpreted as predominently a very light gray, with an extra hint of green and a bigger hint of blue. Or redefined as an HSV triplet of of 220.4 (a greenish-blue hue), 22.5% (relatively unsaturated) and 95.7% (very bright), all consistent with how the sunlit side of an Earthlike world would look with large oceans, vast swathes of terrestrial vegetation and atmospheric clouds, necessarily abstracted down to a very limited number of pixels.

Looking at an actual example of the 'original', seems to give a possible RGB of 0x95B39E (which gives: hue of 138, i.e. a 'bluish-green'; saturation level of 16.8%; brightness value of 70.2%), which is of course also consistent with the above assumptions about Earth. But all such images are of course ultimately derived as a composite of the data from eight separate 'filters', which don't neatly fit into the RGB color model, and always subject to various kinds of post-processing and image conversion techniques.

#2907: Schwa

March 15, 2024

WHAT'S UP? WAS DOUG GONNA COME? DOUG LOVES BRUNCH.

NUH UH, DOUG'S STUCK 'CAUSE OF A TUNNEL OBSTRUCTION. A TRUCK DUMPED A TON OF ONIONS.

UGH.
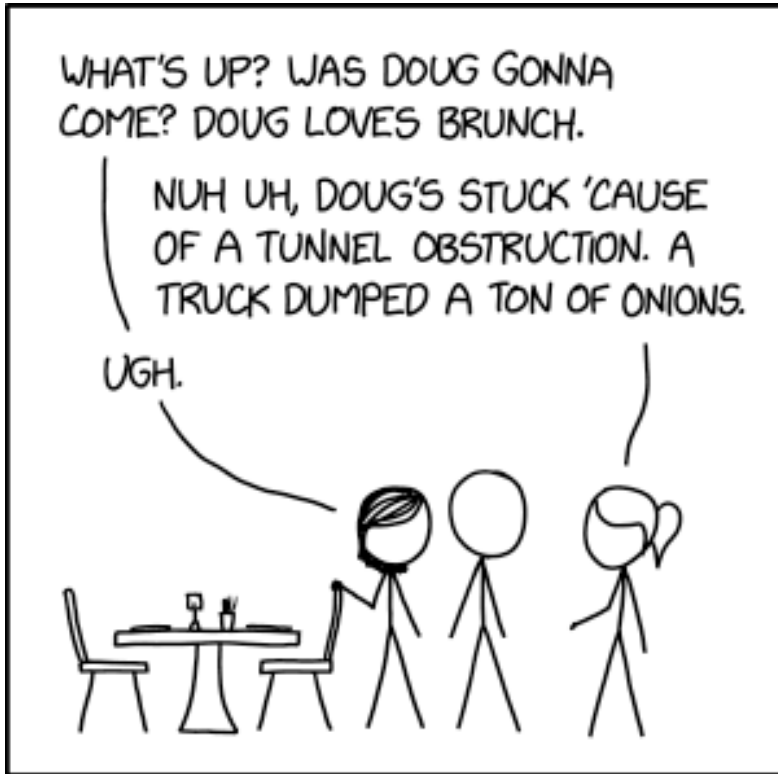
THE SCHWA IS THE MOST COMMON VOWEL SOUND IN ENGLISH. IN FACT, IF YOU STICK TO THE RIGHT CONVERSATION TOPICS, YOU CAN AVOID LEARNING ANY OTHER ONES.

Doug's cousin, the one from London, runs a Bumble love cult.

Explanation

English features a lot of vowel reduction, where vowels in unstressed syllables often become a short 'uh'-like sound called a schwa (ə). As Randall notes, this makes it by far the most common sound in English, and Randall makes the observational joke that one can learn the English language without learning any other vowel sounds, if one sticks to the right topics of conversation. He gives conversational examples which demonstrate exactly that, using words that contain only the schwa vowel. Note that this is accurate only for dialects with the STRUT-COMMA merger, where the two vowels in the word "button" are pronounced the same.

The humor lies in the unusal and impractical elements of this tip:

- It's impractical, since limiting oneself to only words with schwa will exclude using many common words (like "no") and make for stilted speech (using "Nuh uh" every time instead).

- It's highly unusual for hyper-efficient language learning to focus on all words with a common vowel sound rather than, say, the 1,000 most common words. English learners learn between 14 and 20 vowel sounds - depending on the dialect - which are written with just six vowel letters (AEIOU and sometimes Y). For example, the 'a' in "cat" may not be the same 'a' in "father", depending on dialect.

Randall has had a longstanding interest in minimalist visions of English communication. He published a whole book, Thing Explainer, about explaining complex ideas — such as the Up-Goer 5 — using "only the ten hundred words people use the most often."

The intended pronunciation of the conversation can be written in the International Phonetic Alphabet (while preserving punctuation marks) as:

The title text, in IPA, if only schwas were used:

#2908: Moon Armor Index

March 18, 2024
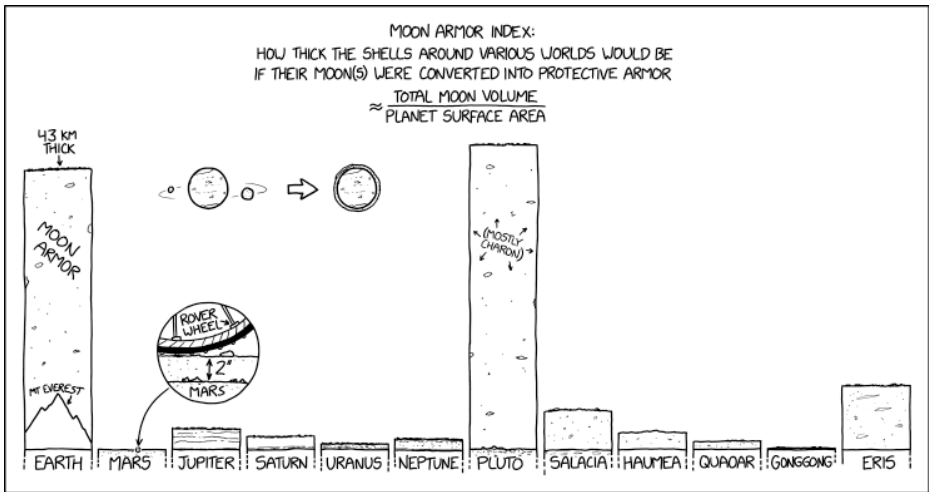
Astronomers are a little unsure of the applicability of this index, but NASA's Planetary Protection Officer is all in favor.

Explanation

In this "What If?"-style comic, Randall hypothesizes an imaginative situation in which each planet's moon(s) become converted into protective armor (as a form of overburden) to coat the respective planet. For example, the Moon would coat Earth in a 43 kilometer layer if it were molded into protective armor, almost five times the height of Mount Everest.

This visual index illustrates that the moons of both Earth and Pluto are unusually massive in comparison to their planet. The large relative size of Earth's moon — and its protective role in deflecting asteroids — is one reason that's been suggested by astronomers for why intelligent life successfully evolved on Earth.

Mars's moons Phobos and Deimos are small compared to Mars, so they would contribute a thin 2-inch layer of 'armor' around Mars, in contrast to the 20-inch (0.5 m) diameter of a Mars rover wheel. Huge Jupiter would be covered with almost 3 km of "moon" matter, which indicates just how much moon mass orbits Jupiter, a situation mostly similar for Saturn, Uranus, and Neptune.

Six trans-Neptunian dwarf planets and dwarf planet candidates are included, as well: Only Pluto, having a moon (Charon) of a comparable size to its planet, would have a layer thicker than Earth's. Salacia, Haumea, Quaoar, Gonggong and Eris are among the ten largest

such objects. (Two dwarf planets with moons — Makemake and Orcus — are not mentioned in the comic, but would be similarly depicted.)

The title text states that astronomers are "unsure" about the applicability of this index, a joking understatement that imagines this comic as being a serious contribution to astronomical academic knowledge. Astronomers might also point out additional issues:

- wariness of moons and planets getting too close.
- moons already serve a protective purpose by deflecting and even intercepting some incoming asteroids (with a slight chance of turning a future miss into a hit).
- the four gas giants — Jupiter, Saturn, Uranus, and Neptune — lack a solid surface to practically sustain a layer of armor without even more ambitious engineering than the already complicated process of somehow distributing soft-landed fragments of disassembled satellite evenly all across a planet.
- although the coating would provide some protection to the underlying surface on which it was placed, it would effectively become part of the planet, and raise the surface. The things we would normally care about protecting, such as any life forms that exist, would be forced to relocate to this new surface, and therefore not benefit from any protection, while suffering significant detrimental impact to habitats, etc.

The title text continues that NASA's Planetary Protection Officer is purportedly in favor of the idea. In

reality, this officer is actually responsible for keeping other celestial bodies safe from Earth's contamination, not for shielding planets in armor. Theoretically, though, armoring other planets could indeed protect them from further Earth-sourced contamination, and armoring Earth would also theoretically protect other planets by burying the biosphere and all of Earth life not already sent into space — a potentially civilization-smothering action, though a surprisingly unapocalyptic result compared to many of Randall's "What If?" scenarios.

Implications of choosing a volume-to-area ratio[edit]

The usual means of comparing a moon to a planet might be to compare the volume of both. This comic compares moon volume (kilometers cubed) to planet surface area (kilometers squared); specifically, the index derives a linear indicator (the thickness of the new material) by dividing the area of the main body (proportional to the square of its uncounted radius) into the combined volume of all other bodies (proportioned cubes of their own radii), which gives an unusual dimensional analysis (dividing X kilometers-cubed by Y kilometers-squared gives a length, Z, in kilometers, not a simple dimensionless ratio).

This particular methodology makes the Pluto-Charon system (Charon being roughly half the diameter and one-eighth the volume of Pluto, before even adding that of the other moons) surprisingly similar to the Earth-Moon one (our sole Moon is around one-quarter Earth's diameter, and therefore less than 2% its volume; also in comparison, the Earth and Moon are respectively slightly more than 150 times and around 3 times the volume of Pluto), but leaves them both as still standing out

significantly against all other planetary comparisons, even against comparably-sized 'planet's.

The complexities of armor thickness calculations[edit]

The comic uses the ≈ sign to show that the formula is only an approximation: it does not take account the increase in armor surface area as it gets thicker. This approximation would be perfect for a shield of thickness zero, but for the thickest shield (Pluto) around a small celestial body the error is around 4% (52.5 km by this approximation, but 50.4 km by more thorough calculation). To find the correct value, we can use the formula for the volume of a sphere, $V = 4/3 * pi * r^3$ (where V is the volume and r is the radius). Using this formula, we can find and add together the volumes of each moon, as well as the volume of the planet, to get a total volume of the new shielded planet. Then we can find its radius using the formula $r = (V / (4/3 * pi))^{⅓}$, derived from the previous formula. Subtracting the radius of the previous planet from the radius of the new planet gives us the thickness of the armor.
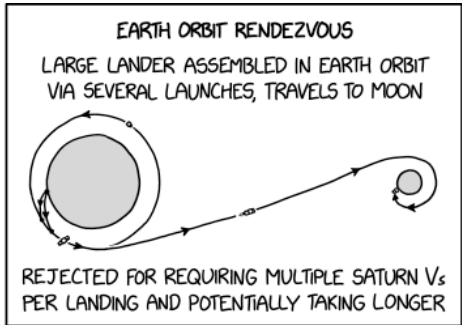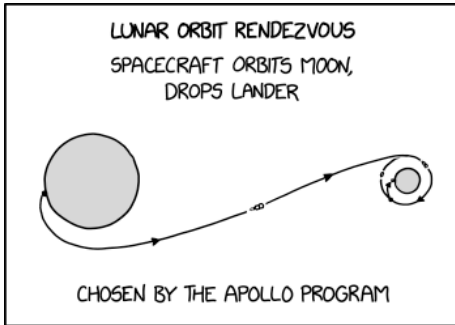
This process described above assumes that all objects involved are completely spherical, which may not be the case. The act of tearing apart a solid moon, perhaps into rough gravel, might add microvoids to the new layering that bulk up the volume slightly. But neither are gravitational compression effects taken into account on an originally loose material; the planet's gravitational pull could settle some of the moon material into a slightly smaller volume than the one it occupied as lower-gravity moon.

The planet below could also be marginally affected by the change in its total planet-and-armor mass, for rocky planets mostly within

any pedosphere or previously exposed outer lithosphere. The interaction with surface liquids and atmospheres, especially in planets defined primarily by their gas layers, would depend much upon how impermeable and/or rigid the chosen layering method made the additional material. One could imagine a spherical shell of moon matter around Jupiter with such high structural strength as to resist crumbling into its gaseous maw. Alternatively, the moon material could be expected to sink towards the gaseous planet's center until it reaches a layer sufficiently dense and/or rigid to stop it sinking further. In this case the moon material would displace a volume of the planet's gas causing an increase in the planet's radius.

#2909: Moon Landing Mission Profiles

March 20, 2024

LUNAR ORBIT RENDEZVOUS
SPACECRAFT ORBITS MOON, DROPS LANDER

CHOSEN BY THE APOLLO PROGRAM

EARTH ORBIT RENDEZVOUS
LARGE LANDER ASSEMBLED IN EARTH ORBIT VIA SEVERAL LAUNCHES, TRAVELS TO MOON

REJECTED FOR REQUIRING MULTIPLE SATURN Vs PER LANDING AND POTENTIALLY TAKING LONGER

DIRECT ASCENT
LANDER LAUNCHED FROM EARTH DIRECTLY TO MOON

REJECTED FOR REQUIRING AN UNREASONABLY LARGE ROCKET

LUNAR EARTH RENDEZVOUS
MOON TRANSITS TO RENDEZVOUS WITH SPACECRAFT IN LOW EARTH ORBIT

REJECTED BECAUSE I GUESS NO ONE THOUGHT OF IT?!

If you pick a low enough orbit, it gives you a lot of freedom to use a lightweight launch vehicle such as a stepladder.

Explanation

Getting astronauts to the Moon (and back) is hard. There are several different strategies to do it. This comic reviews three mission profiles considered for the Apollo Moon landings and one which is absurd. (While the profiles only depict the outbound leg of the trip, in each case the return journey would likely make compatible rocket and trajectory choices.)

Lunar Orbit Rendezvous (LOR)

Description: Using a single large rocket to get the required lunar orbiter and lander systems into trans-lunar orbit, which can then fulfil their eponymous roles.

Status: Chosen by the Apollo Program in the 1960s and 1970s.

Explanation: This was the actual method used in the Apollo missions. It was efficient in terms of fuel and cost. The main spacecraft ('command module') orbits the Moon, as the lander separates and uses its descent-stage to safely reach the surface.

After the Moon mission, the lander (ascent-stage only) ascends to dock once more with the command module in lunar orbit, the crew then return to Earth in the command module (leaving the abandoned ascent stage behind, in most cases purposefully directed to impact the Moon).

Earth Orbit Rendezvous (EOR)

Description: A large lunar-landing system is assembled in Earth orbit through several launches. Once complete, it travels to the Moon as a whole. It is depicted here as not required to orbit the Moon in full, in any way, but is shown needing to orbit Earth, as an unavoidable part of its profile.

Status: Rejected for requiring multiple Saturn V rockets per landing and potentially taking longer.

Explanation: This concept involved launching different parts of the spacecraft into Earth orbit using multiple rockets and then assembling them before heading to the Moon. It would have allowed almost arbitrarily large sizes of equipment to have reached the surface, perhaps to simplify the return journey, but with the complication of adding multiple orbital docking procedures to the project rather than most assembling and spacecraft mating being carried out prior to launch. It should be noted that Randall made a mistake on this point of the comic; the Earth Orbit Rendezvous would have required multiple launches of the Saturn IB, not multiple launches of the Saturn V.

In theory, a returning craft (the final stage that breaks free of the Moon and heads back to Earth) would have made a direct crossing from the Moon's surface back to Earth's atmosphere, unless a Lunar Orbit aspect (perhaps a habitation module left as a waypoint for use by subsequent missions) was included in the plans. (In this

particular regard, the Artemis program profile resembles this particular profile.)

Direct Ascent

Description: The lander is launched from Earth directly to the Moon without entering orbit.

Status: Rejected for requiring an unreasonably large rocket.

Explanation: This was a simpler but less feasible approach, where a single huge rocket (or a particularly large rocket stack) would send the lander straight to the Moon. The inefficiency comes in taking a comparatively huge rocket down to the Moon and back up, requiring a lot more fuel than a separate lander. It avoids having to 'park' items in orbit that it must later dock once more with, but then increases the mass that must land on/take off from the lunar surface, without being useful during this phase of the mission.

The return journey would be as direct as the original leg. This option does not preclude discarding various stages of the rocket as various transit phases are completed, but would not involve any complicated rendezvousing to enable the crew module to reach its waypoints.

In reality, this was the approach imagined for the Nova C-8 rocket as an Apollo alternative. This was also the approach used in Destination Moon from The Adventures of Tintin, with the fuel problem addressed by using a nuclear reactor for much of the trip—which

would be a really bad idea in reality since "rockets have a tendency to explode". Science fiction movies have frequently depicted this method of landing, either before the dawn of the actual Apollo program or (to save plot-time or by using a fictional increase in rocket capability) in more futuristic settings.

Lunar Earth Rendezvous (LER)

Description: The Moon transits to rendezvous with a spacecraft in low Earth orbit.

Status: Rejected because, humorously, "I guess no one thought of it?!"

Explanation: This is a fictional and impractical scenario. The Moon cannot propel itself and cannot alter its orbit to rendezvous with a spacecraft.[citation needed] The Moon would also break up because low Earth orbit is within the Roche limit. Astronauts would theoretically land on the Moon, but the hypothetical fragments of the Moon would make the landing impractical. This would be also bad for the Earth's climate, tides, stock markets and ecosystems.[citation needed]

The 'return leg' could involve having the Moon move back to where it should be, which does not add too many extra mysteries to the mission profile, unless those who implement it would prefer not to have to bring it back again for the next expedition.

The title text imagines the Moon coming to very low Earth orbit, low enough to reach with a step ladder.

There are many reasons this is wholly impractical, as well as civilization-ending. Dropping the Moon down to within six feet or so of the Earth would likely cover the Earth in moonrock. The only difference from the prior comic is that debris would ultimately be deposited at a significantly high sideways velocity (perhaps briefly preceded by a hypersonic atmospheric shockwave and everything you might expect from catastrophic worldwide ground-tremors), no matter where you were. If this mission profile had been used in the 1960s, the Soviet Union, the United States, and all other nations (whether they like it or not) would have 'won' the space race almost simultanously as the rapid redistribution of rock tried to settle over everywhere to create (on average) a 43 km-deep grave. Arguably the true 'winner' could be determined by which country gets hit by the initial Moon rocks first.

Factual Mission Profiles[edit]

The Apollo Program considered a number of possible mission profiles. Of the four shortlist plans, the Lunar Surface Rendezvous plan was not shown or mentioned in this comic, but clearly inspired the title of the method created in its place.

With the ongoing work to achieve the Artemis program, the successor to Apollo, this comic is probably also making sideways references to the plans and equipment being developed to achieve it, which currently features several aspects of the above examples. A single crewed-launch is intending to rendezvous with, and make use of, additional equipment separately launched (including one that is very nearly one big rocket in its own right). Instead of

assembling in Earth orbit, it will probably make use of a lunar near-rectilinear halo orbit, or NRHO, to and from which the landing system will operate. There is also planning, still in an early stage, to establish lunar-surface infrastructure that would simplify the refuelling of the transfer craft and support surface operations.

The only depicted plan that should not play a part in upcoming missions is the one which may be more connected with some other quite different scenario which has previously been referenced in xkcd.

#2910: The Wreck of the Edmund Fitzgerald

March 22, 2024

Panel 1:
THE SHIP WAS THE PRIDE OF THE AMERICAN SIDE

IT WAS DUE TO SET SAIL FOR CLEVELAND

AS THE BIG FREIGHTERS GO, IT WAS BIGGER THAN MOST

WITH A CREW AND GOOD CAPTAIN WELL SEASONED

Panel 2:
BUT TAKING A WALK ON THE SHORE BY THE DOCK

WAS A SONGWRITER NAMED GORDON LIGHTFOOT

HE WAS HUMMING A TUNE BUT IT DIDN'T HAVE WORDS

FOR IT'S CHALLENGING TRYING TO WRITE GOOD

Panel 3:
POOR GORDON SOUGHT GLORY BUT NEEDED A STORY

HIS CAREER IN FOLK MUSIC IMPERILED

HE MULLED OVER THIS AS HE WATCHED THEM DO WORK

ON THE HULL OF THE *EDMUND FITZGERALD*

Panel 4:
PERHAPS IT WAS WRONG, WHAT HE DID FOR A SONG

HE SHOULD NEVER HAVE BRIBED THAT MECHANIC

BUT HIS MARITIME CRIMES ARE NO WORSE THAN THE TIME

YOUNG JAMES CAMERON SANK THE *TITANIC*

You know that asteroid that almost destroyed Earth in the 90s? Turns out the whole thing was secretly created by Michael Bay, who then PAID Bruce Willis and Ben Affleck to look heroic while blowing it up!

Explanation

The comic features Cueball on a pier with a guitar, sharing a conspiracy theory about the origin of Gordon Lightfoot's song 'The Wreck of the Edmund Fitzgerald'. This song, which was one of the most recognizable and successful of Lightfoot's career, recounts the fate of the SS Edmund Fitzgerald, a Great Lakes freighter which famously sank during a storm on Lake Superior, resulting in the deaths of the entire crew.

The song was written only a few months after the incident. In Cueball's version, it was Lightfoot himself who engineered the wreck, in order to provide material for lyrics to fit a tune he'd already composed. Cueball then goes on to suggest that a "young" director James Cameron engineered the much greater maritime disaster, the 1912 sinking of the RMS Titanic, so he could create a film about it 85 years later (when Cameron was 42 years old).

This theme is carried further in the title text, which suggests that director Michael Bay created an actual asteroid in the 1990s and directed it toward the Earth, in order to provide material for his film Armageddon. However, there was no such asteroid: unlike the other examples, this film was not based on real events.

The first, third, and fourth lines of Cueball's song are identical to the 9th, 11th, and 12th lines of Lightfoot's. Cueball's second line, "It was due to set sail for

Cleveland" does not match Lightfoot's 10th, "Coming back from some mill in Wisconsin", but is closer to Lightfoot's 14th line, "When they left fully loaded for Cleveland". It is possible that Randall made this change in order to tighten the otherwise fairly loose rhyming scheme of the song. After Cueball's first four lines, his song departs significantly from Lightfoot's.

In real life, the cause of the ship's sinking remains unknown, but it's speculated that the ship's hull broke up in the rough waters of a storm. Lightfoot, who wasn't involved with the ship at all, devoted considerable time, effort and money to the families of the disaster's victims. In addition, while the comic presents Lightfoot as desperate for a career-making song, he was already internationally famous, with multiple hits, when the wreck occurred.

Only a day after the comic was released (March 23rd, 2024) a YouTuber recorded Randall's version of the song.
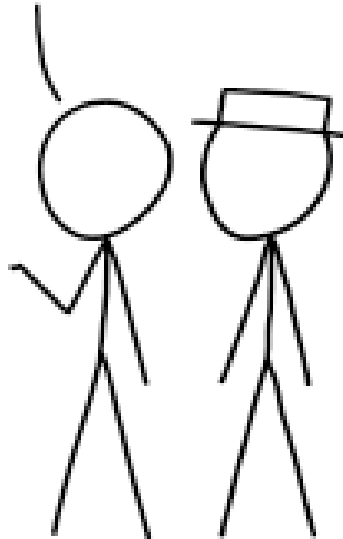
The Mercator projection drastically distorts the size of almost every area of land except a small ring around the North and South Poles.

Explanation

Because the Earth is curved, all flat maps have some distortion. (A common comparison is flattening an orange peel, which cannot be done without tearing or stretching or wrinkling parts of it). Different map projections can distort different metric properties, such as distances, areas, and angles, while leaving others intact. It can be desirable to preserve different metrics in different applications.

The Mercator projection, depicted in the comic, prioritizes depicting correct angles. This allows for easy course planning at sea, and makes shapes fairly accurate. In exchange, Mercator is often criticized for distorting size: distances near the poles look larger than the same distance near the equator. A common complaint is that Greenland appears as big on the map as Africa, when Africa actually has 14 times as much area as Greenland. When these size distortions are presented out of context, they can create bias and misconceptions about different places.

Cueball's dialogue leads the reader to expect this complaint. However, instead of comparing relative sizes of two landmasses within the map, Cueball compares the absolute sizes of the depiction of Greenland and the actual Greenland. On a typical world map, Greenland might be centimeters or inches across. Judging from the human characters, the mapped Greenland in this comic might be 10 cm across. In real life, Greenland is about

650 miles or 1,050 km across from east to west. Cueball deems this difference misleading, presenting it as a failure of this specific map or projection.

Of course, this is absurd. The purpose of any map is to present information at a scale (usually much more compactly) at which it is easy to read and interpret. Any actual-size world map would have to be the size of the Earth's surface, in which case it would have few uses. In addition, if a map includes a scale, it enables the user to use the ratio to calculate the actual size of the places depicted (though this would not be possible on a Mercator projection, since the map-to-reality scale is not constant).

The title text is about the fact that regardless of the size of the map there is a certain point where the area on the map is equal to the area at the actual pole at that latitude. This is because a horizontal line on a worldwide Mercator projection corresponds to a line of latitude. While most lines of latitude are thousands of miles (kilometers) long, they become smaller and smaller approaching the poles. As long as the projection (and choice of how much map to print) includes the pole (a point of zero length) expanded out as a measurable edge of the map, there will be a line of latitude around each pole whose length would equal the width of the map that Cueball is looking at (though the specific line would be different depending on the size and precise geometry of the map). If Cueball's map were 1 m wide, then this line of latitude would be at 89.999998568° N or S - that is, the line of latitude there would be a circle with a

circumference of 1 m around each of the poles. Of course, in order for the map to actually include (say) the northern of those latitude lines as well as the equator, it would have to be over 3 meters tall.

The idea of a 1:1 map was expanded in Jorge Luis Borges's "On Exactitude in Science".

Mercator projections have been mentioned previously in 977: Map Projections, 2082: Mercator Projection, and 2613: Bad Map Projection: Madagascator. The misleading size of Greenland on the Mercator projection is also the object of 2489: Bad Map Projection: The Greenland Special.

#2912: Cursive Letters

March 27, 2024

EASY TO TELL WHAT LETTER IT'S SUPPOSED TO BE

LOOKS COOL ⟶
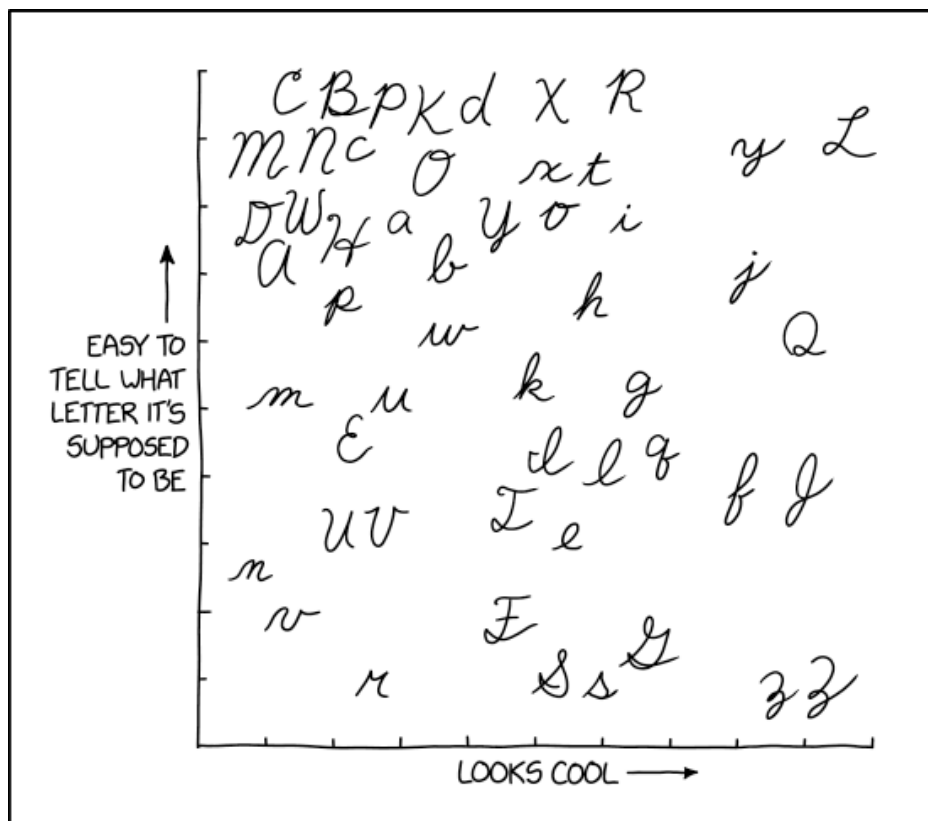
Explanation

This graph ranks cursive Latin script letters. The type of cursive used is closest to D'Nealian though a few of the letters appear to be in the Zaner-Bloser style of cursive (specifically the P, Q, and p). The graph uses two criteria: legibility and coolness. According to the graph in the comic: 'L' is in the top-right quadrant indicating it is both cool and easy to read; 'C' is in the top-left, meaning it is easy to read, yet not cool; 'Z' and 'z' are in the bottom-right which means cool looking, yet not easy to read; and 'r' which is bottom-left indicating it is neither particularly cool nor very easy to read (perhaps being confusable as a form of 'n', or even 'M', at least until actual cursive versions of those are comparable against).

The purpose of cursive is to allow efficient handwriting and make characters look nice and more "connected" at the same time. This is a particular issue when writing with a quill or fountain pen which tends to make noticeable marks when lifting the pen, so joined letters are generally neater than separated ones. The possible downside of this is the legibility of the individual letters. This may be due to the similarity of cursive letter shapes (e.g. 'U' and 'V' or 'e' and 'l' in the graph), especially when joined to other letters, or due their dissimilarity from more familiar "block letter" counterparts (e.g. 'Z' and 'z' in the lower right corner).

In the title text, Randall states 'L' and 'q' are letters that he enjoys writing in cursive, which could possibly add a

third axis (most fun to least fun) to the graph. Notably, some RSS apps have challenges displaying the font and result in settings of ′???′s.

The title text is written in cursive-looking font using upper unicode characters (encoded as UTF-8). Example: the cursive ′I′ character (Unicode 120024 U+1D4D8) is F0 9D 93 98 in UTF-8.

The title text includes 22 of 26 characters in the English lowercase alphabet and is thus 4 characters short of a pangram (missing letters: j, v, x and z). Pangrams are often used to show all the characters in a typeface in print or on a computer screen. It is unclear if the comic deliberately chose the words in the title text to show almost all the characters in cursive or if it is simply a coincidence.

To benefit those with lacking Unicode support, the title text reads: ″I think capital L is probably the most fun to write, though lowercase q is also a strong contender.″

#2913: Periodic Table Regions

March 29, 2024
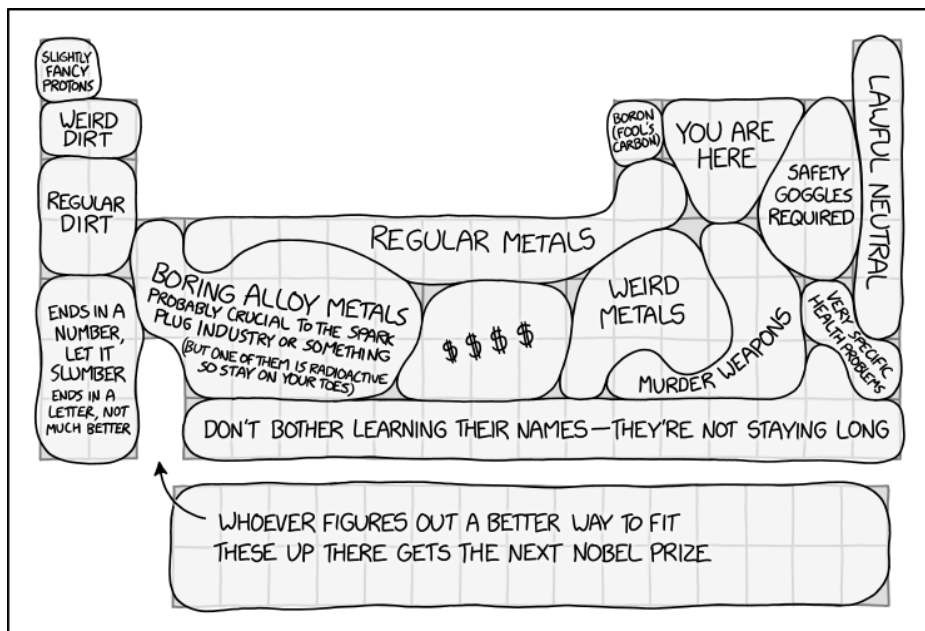
Cesium-133, let it be. Cesium-134, let it be even more.

Explanation

The periodic table is used to arrange chemical elements based on their properties. This comic groups them together into regions with labels humorously reflecting their properties, characteristics, or uses.

Table Sections[edit]

The periodic table of elements has previously been the subject in 2214: Chemistry Nobel, 2639: Periodic Table Changes, and 2723: Outdated Periodic Table. It is also referred to or indirectly referenced in a number of other comics, such as 18: Snapple, 821: Five-Minute Comics: Part 3, and 1052: Every Major's Terrible.

HOW COOL A SOLAR ECLIPSE LOOKS
BY POSITION ALONG THE PATH

COOLNESS

"WE SHOULD HAVE A GOOD VIEW HERE—WE'RE PRETTY CLOSE TO THE MIDDLE OF THE PATH."

"YEAH, THIS MAP SAYS THE SUN WILL BE 91% ECLIPSED!"

|←——— PARTIAL ECLIPSE ZONE ———→|←——— PARTIAL ECLIPSE ZONE ———→|

PATH OF TOTALITY
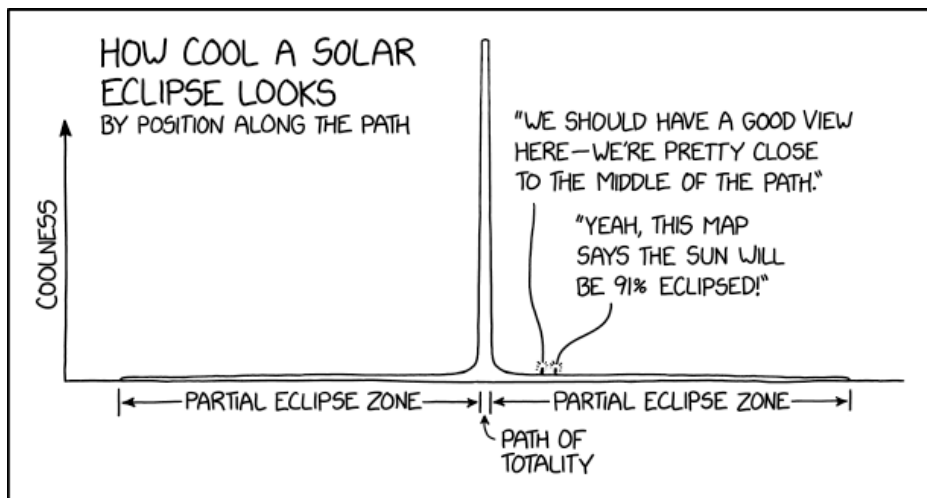
A partial eclipse is like a cool sunset. A total eclipse is like someone broke the sky.

Explanation

A total solar eclipse occurred in North America on April 8, 2024, a week after this comic. A solar eclipse occurs when the Moon moves between the Sun and the Earth, but in order for it to be a total eclipse, the Sun, Moon and the observer's position on the Earth need to line up nearly exactly, and at the right distances (if the Moon is too far away, the eclipse will be annular, rather than total). When such a phenomenon occurs, there's a "path of totality", referring to the range of locations where such an alignment occurs (though only for a few minutes in each location). Away from, but near to, the path of totality (and outside of the specific time of totality), the Moon partially obscures the Sun. In Boston, where Randall lives, the Sun will be 93% obscured at the local peak of the eclipse.

The comic refers to the fact that the human eye is very good at adapting to different levels of light intensity. At 95% occlusion, it's noticeably dimmer outside, but the effect is similar to light in late evening, or on a heavily overcast day, nothing particularly remarkable. Using eclipse glasses (or a simple pinhole camera), it's possible to see the Sun being occluded, but someone unaware that an eclipse was occurring would barely notice that anything was happening.

Within the path of totality, it's a different situation. Though an eclipse for any given locale could be experienced at all times from dawn to dusk, the most

dramatic ones will occur somewhere around the middle of the observer's day. When the Moon fully obscures the Sun, for a brief period of time, the area becomes almost fully dark without the usual or expected crepuscular transition. Temperatures drop noticeably in a matter of minutes and wildlife (and people) may react in unusual ways. The level of light in the rest of the sky is similar to that which accompanies a sunset, but in all directions and without the horizon's red light effect. Most dramatically, the previously unseeable Sun's upper atmosphere can be viewed, as a ring around the dark circle of the Moon, with the naked eye (which should only be possible once the bright solar disc is obscured, and until it starts to appear again). At the very limits of totality, though perhaps most dramatic at its ending, the smallest sections of the bright solar surface will briefly be the only parts to shine through low points on the Moon's edge to form Baily's beads, or a "diamond ring" effect, not at all visible beyond the narrow central strip of the eclipse.

The graph in this strip points out that the difference between 91% (or even a 99%) eclipse and a total eclipse is dramatic. An almost total eclipse is barely noticeable, while a total eclipse is a visual phenomenon unlike any other. This is a situation where being close to the path of totality and being on it makes a huge difference.

Forbes made a similar reference to total solar eclipses being only worthwhile seeing if in the direct path of 100% totality, with a "map of nope". The map shows all of North America that's not directly in the 100% path of

totality as "Nope" meaning that anyone in those areas won't experience the full "OMG!" experience of the total solar eclipse. The article mentions hotels may claim to be close enough to the eclipse with "nonsensical oxymorons like '99% coverage of the full total eclipse'" and that it is common for people to think: "I'm happy to avoid the traffic and settle for 95%'".

The title text simply emphasises the point of the comic - the significant difference between a partial and a total eclipse. It is unclear whether the claim is that a partial eclipse is really 'like' a sunset, while a total eclipse seems like someone broke the sky — claims which would be hyperbolic — or if the intention is to say that the comparison between a partial and total eclipse is equivalent to the comparison between a cool sunset and a broken sky.

Randall has earlier made many comics about the 2017 total solar eclipse, such as 1876: Eclipse Searches through 1880: Eclipse Review and 2816: Types of Solar Eclipse. Randall and his wife also made plans to see the 2024 eclipse in 1928: Seven Years.

Additionally, the graph appears similar to a Dirac delta distribution.

#2915: Eclipse Clouds

April 03, 2024
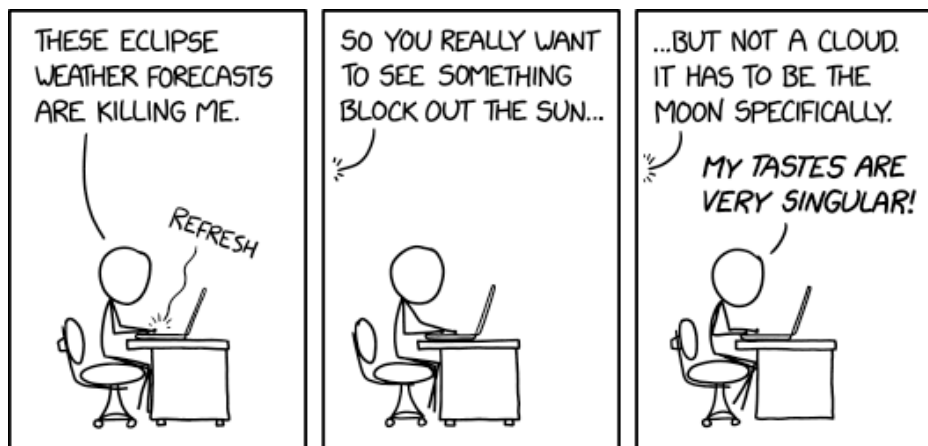
The rare compound solar-lunar-nephelogical eclipse

Explanation

Following on from 2914: Eclipse Coolness, Randall makes another comic about the solar eclipse occurring on April 8, 2024. Cueball is checking the weather forecast. At the time that this comic was posted, much of the eclipse path was projected to be overcast, and Cueball expresses disappointment as someone wishing to watch the Moon slowly block out the Sun (and not the clouds obscuring both). The off-panel voice points out the mild irony that he wanted to see something block out the Sun, so the clouds technically fit his wish, leading Cueball to exclaim that he has a specific taste for things blocking the Sun.

The title-text references the 'alignment' of Sun, Moon and cloud (Nephele [νεφέλη] is Greek for cloud), describing it as rare, although this is not really as desirable as it might make it sound. Sun/Moon conjunctions are already quite rare, so that the balance against Sun/Moon/no-cloud probabilities isn't really so notable. In theory, it should equal being the difference between cloud and no-cloud on any average day for your chosen location. In practice, scholars such as Edward A. Murphy and Finagle would argue that conjunctions of the Sun, Moon, and clouds are considerably more likely than a Sun/Moon conjunction occurring on a sunny day.

Note, as of the posting of this comic the weather reports had consistently shown the Eclipse path in Northern Vermont, New Hampshire and Maine, the points nearest

to Randall's actual home in Cambridge, MA, to have the best potential viewing in the country with near 0% projected cloud cover. While this should in theory negate Randall's anxiety, the historical forecast called for a 75% chance of cloud cover and may have prompted Randall to make other plans like visiting friends or family in sunnier portions of the eclipse path like Texas. Randall may therefore be still faced with the choice of altering his eclipse viewing plans, even if the situation technically favors New England. Nephological means "related to clouds".

#2916: Machine

April 05, 2024

[VISIT XKCD.COM TO VIEW]
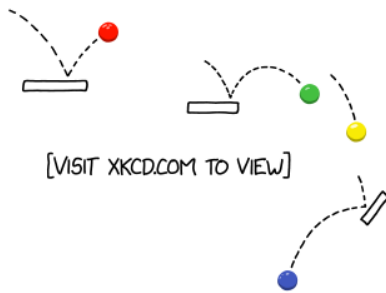
The Credible Machine

Explanation

This interactive game is the 14th April fools' comic released by Randall. The previous April fools' comic was 2765: Escape Speed from 2023, which was released on Wednesday, April 19, 2023. "Machine" has been updated multiple times in the weeks following its release, adding the following features:

- the trophy and shot glass props
- the cat, which swats balls in front of it
- the inanimate kitten and bun decorations
- a system of links, which encodes the XY coordinates of the currently viewed cell, and the time (i.e. the entire machine's state after a certain moderation action)
- a button to follow a nearby ball as it traverses through the machine, also preventing it from despawning

As referenced in the title text, this game is a spiritual successor to the 1990s and early 2000s PC puzzle game series The Incredible Machine, a game Randall played as a kid. Both games have several objects in common:

- fan
- cat
- ramps
- balls of varying densities

The comic starts in a main screen where the user can create a Rube Goldberg machine in a "Cell" where the

goal is to route a constant stream of colored balls from inputs on the ceiling or walls to outputs of matching colors on the walls or floor. After the comic is first opened a window pops up over the machine where Cueball in a lab coat tells you to route the balls from the inputs to the outputs. A button opens a "tool panel" where there are large and small boards available for use, as well as some gimmicky stuff like prisms (which deflect marbles) and fans (which blow marbles around), plus decorative elements which have no effect on the balls.

Typically, inputs and outputs only accept balls of a single color. However, some outputs accept multiple colors, indicated by a double arrow, and some inputs produce multiple colors. When the player is designing their 'machine', this will involve multiple full streams merged into one (supplied by a double-exit on the adjacent submission). Machines now working in the full grid may, however, find that their sources now contain stray balls of other types that were not handled properly, but there is no way to force a re-edit of the machine to alter its behavior to account for this.

If any balls are left in your cell for more than 30 seconds, they fade away. The first time a ball fades away another popup informs you that the balls are removed for security reasons. An indicator next to each exit increases for each ball of the correct color that passes through an exit, and reduces when no balls pass through, or if balls of the wrong color pass through it. While that exit is not properly supplied it displays a red cross, which changes to a green tick when a sufficient, and sufficiently clean,

stream of balls is supplied. The first time you have built a machine which succeeds in routing enough balls of the correct color to all relevant outputs, a popup will prompt you to submit your cell to be added to the public machine. (Subsequently, the submit button will quietly change from 'inactive' (pale) to clickable (dark). This will change back again if any ball transfers dip back below the required threshold for any reason, such as further editing or an end to a 'fluke' glut of accumulated balls.)

Choosing to submit your cell will give you a textbox to give this cell a name. Proceeding through that, you will now see your cell within the 'grid' and a 'live' feed of balls from any relevant neighboring cells (which may be more sporadic then the feed you designed your cell with, and contain stray balls of different types). If any supplying-neighbors are still marked as "under construction", they may provide the balls as if perfectly routed from their own (eventual) source, but will eventually dry up. If your newly submitted creation is placed in the lowest row of cells, balls will be dispensed through the exit at the bottom, but there will be no launcher to propel them towards the pit, and they will vanish as they leave the exit.

Upon reopening the link to this comic without coordinate and time parameters, your recently created machine will most likely not be visible in the space you built it in. Reddit user xzaphenia has claimed on r/xkcd that this is because there is a moderation team (of which they are a member) and that the main page only shows public, approved machines. This team of people,

including those credited as co-creators of this comic, select machines according to their preferences (and little to no formal criteria besides coolness, innovativeness, effectiveness, and privacy concerns). Given the number of 'bottom-layer' cells that are likely primed ready to be completed (e.g. the grid-width of twelve, perhaps staggered across adjacent rows) and the many possible worldwide contributors at any one time, it may be that the chances of being picked for permanence is low; and certainly would have been lower early on in the comic's existence during the initial frantic rush to participate. It is also claimed that at some point, moderation will be cut off and the machine will be considered "complete".

- Introduction popup
- Time limit popup
- Submission popup

The button in the bottom right corner allows you to toggle between editing your own machine and a page where you can drag around to view all of the machines that have been submitted and accepted, with a title for each in the upper left corner. In this view you can see that all of the outputs are also inputs for another cell, except for the top row where the inputs come from off screen and the lowest row which output through a launcher of some kind to a set of four colored-coded containers far below. Any empty cells are marked off by yellow tape with the words "UNDER CONSTRUCTION" as well as "DJIA ↑ 31415" once in each cell. "DJIA" stands for the Dow Jones Industrial

Average, with "DJIA ↑ 31415" indicating that it rose to 31415 points, 31415 being the first five digits of pi, without the period. This would often be displayed on a yellow 'ticker', which might look superficially similar to the yellow barrier tape.

When viewing the whole machine, a button in the bottom left corner, added later, allows you to follow the path of the nearest ball as it passes from cell to cell. This will also make the ball you are following immortal - not subject to the 30s timeout rule. However, it will stop following at the bottom of the base machine -- it will not follow into the bottom holding containers, nor keep it immortal once down there. Another later addition was a button in the top left corner which copies a URL that will take you directly to the current cell that you are viewing. However, the link that is created will always show you the version of the machine at the time that you were viewing it, without any subsequent additions.

Whenever balls reach the bottom of the grid, they are directed towards four containers, one of each color. Most balls are accurately sent to their appropriate container, though there are some misfires. These containers are above a pit, and dump their contents every 11.5 seconds. Balls in the pit are subject to a 97 (approx) second culling rule (including time spent in the holding containers), unlike the balls in the cells above. If no balls are directed towards the containers, the pit will be empty. If at least one stream of balls is making it, Cueball and Megan sit in a small boat named the USS Buoyancy, and when sufficient balls are being deposited, the boat begins to

float and move. Balls that miss or overspill the pit fall out of the bottom of the frame.

Under construction cells will feed balls of the appropriate color into neighboring cells so long as you are not looking at them. Once you scroll to look at them, the supply of balls stops and subsequent cells in the chain will not receive any; scroll away from them again and the supply will resume.

The grid is 12 cells wide, and grows in height. The largest size observed so far is 12x128, for a total of 1536 cells. The machine's height is determined by the lowest cell; this can be either your submitted cell, or a cell created by another user.

Imperfections in the machines (whether accidental or by design) and the impossibility of entirely avoiding collisions when crossing streams inevitably lead to significant levels of losses and pollution with the wrong color balls. Indeed, using the follow ball function appears to demonstrate that it is quite rare for a ball to survive more than several machines without getting stuck somewhere. This should mean that effectively no balls would reach the lower layers. This implies that there is some 'creative accounting' going on to ensure that cells lower in the grid still have balls to process - simulating flow only for a few nearby cells, while assuming that those cells themselves have pure, steady inputs.

There is a hard limit of 100 items (both physically interactive and purely decorative) that can be placed in

any given arena. If you have placed 75 items, a count will appear in the component bar of your piece-count ("##/100"), which will go away again if you delete items to bring it below this count. The count text turns red at "100/100", at which point no more items can be added, only existing ones moved (or removed, to lower the count again).

Toolbox items[edit]

All other items can be manually re-angled by a 'loop node' arm extending from the bounding box. If you cannot see the 'angle node' for such a selected item, which is normally at the top of any freshly placed item but follows any re-angling that may have already applied, it could be that you have placed the item too close to the edge in which direction the node extends. To rotate it, move the object away from the edge to access the construction node (after which, you can drag the object back if required – but see below).

Rotation may be limited by the minimum bounding box that is the 'selection box', this is not necessarily the more flush convex hull of the collision-map built into the graphic. Should a corner of the bounding box need to move across the edge of the build-area, it will do nothing more than touch the edge until there is sufficient angle-drag to snap it to the angle from which that corner now comes back away from the edge; or, when it has a long straight edge currently flush with the edge boundary, it may snap to exactly 180°, in rotation, whereupon the opposite long straight edge is flush to the construction area edge. All objects that are drag-moved, similarly, cannot be moved any further than their current bounding box touching the construction-area edging.

The bounding box for the rotating wheel is a notable exception to this, being not under any direct angle-control by the player. Instead, it seems to use the bounding inscribed circle that defines the wheel edge iteslf.

Apart from some interactions between the hinged scoops and any element (including other hinged scoops), there is no preventative 'collision detection' between objects during user-placement, which may overlap/cover each other (the most recently spawned item graphically overlays any earlier one). The wheel object will only spin if not constrained by other physical elements (including the spokes of an adjacent wheel, not in counter-rotation) but can still be dragged and placed anywhere within the boundary of the construction area.

The continuous stream(s) of balls respect all tangible objects, which includes any currently being dragged/rotated, though may prematurely vanish if forced between two items moved to touch/overlap each other. It is possible to indirectly nudge balls by carefully moving a tangible object's surface into them (or holding them within it, e.g. the "cup"). This may be useful for rescuing temporarily stray balls (before they time-out anyway), unjamming an area with a construction-induced glut or for testing a ball-path that is not currently being fed 'naturally'. Doing so can then conceivably fulfil all the exit-gate requirements (temporarily), as it might also transiently spoil some required routing, but the manual intervention will not be possible once a 'machine' has been submit.

Non-player items[edit]

Ball containers at the bottom of the machine

Cueball and Megan in the USS Buoyancy

Pit below the USS Buoyancy (not to scale)

Color routing[edit]

The different ball colors have different physical properties. Red balls are more bouncy than other balls, green balls are heavier, and yellow balls are lighter and slightly bouncy. The following values were extracted from the code:

Balls also have spin, but it is subtle and hard to see because the balls have no visible texture.It can be seen, with effort, using green balls (which are heaviest). Rolling down a slope (say, two boards), green balls accumulate spin in the direction they are rolling. Let them drop off the end and then bounce off a brick such that they travel upward, but with very little sideways motion. Then "catch" the balls with a brick just past their apex, when they are moving slowly. If the ball lands on a horizontal brick, it can be seen that the ball will suddenly accelerate left or right based on the spin.

For certain combinations of inlet and outlet 'gates', it is necessary to 'cross the streams'. e.g. to direct righthand-entry balls to a lefthand-exit and vice-versa. It is possible to just construct the field to send two (or more!) sets of balls to fly across a common gap, to land on an appropriate reception area that leads to the chosen exit. But, though this is not completely inadvised, the timing of the balls cannot be guaranteed to be in sync (or, rather, anti-sync) with each other and collisions will occur, especially under the variations of delivery that might significantly alter the ballistic path across the gap. Even if the trial machine works, in isolation with a steady stream of all balls entering the field of play, once submitted it will inevitably be fed by a more

chaotically-routed preceeding construction.

In order to maintain sufficient correct arrivals at exits, it may be necessary to add a method of filtering the hues.

This could just mean introducing a 'wrong hue trap' beyond any crossing point(s) that send the occasionally wrong ball back to the cross point (or let them time-out in a dead-end, relying upon few enough failures from the rest of the balls, along with all colliding balls that subsequently missed any chance of reaching an exit). Alternatively, two (or more) feeds of marbles could be fed through a deliberate 'sorter' that does a sufficiently reasonable job of separating the combined sets out towards their intended target-exits.

The various physical qualities of the balls suggest a number of methods for redirecting separate hues to separate onward journeys. This can be done by isolating a hue from every other hue, then passing on (if necessary) to a setup extracting a different one from the remainder, and perhaps also a third time. It may also be possible to merge 'arrangements' of sorting mechanics to efficiently distribute straight into three or even four onward tracks towards the desired outputs, but that is left as an exercise to the reader.

Even when not strictly necessary for one's own submission, once submitted into the full playing grid the player's own contribution may find itself working with less 'pure' delivered ball-streams (from an imperfectly separating feed-in contribution). It is possible that this more interactive disruption can make the new setup behave erratically or even entirely incorrectly.

It might be thought good practice (but not necessary) to deliberately combine any or all inputs and do a full job of splitting them again, just in anticipation of possibly having to deal with such cross-contamination and being able to 'clean up' the onward stream(s) for the benefit of others. This would of course be particularly difficult if the isolated building-phase does not provide all four hues to 'test' against, so any speculatively added filtering would have to be added 'blind' (and only on the offchance that any anticipated incorrect balls will actually enter the arena) and without any legitimate exits to which such rejects could be shunted (therefore could accumulate, up until any 'time out' that might apply to any ball once operational as part of the combined grid).

Single-input/single-output designs might not particularly require any sorting mechanism, in theory, though the unexpected 'contamination' of the system with balls of different masses/etc could perhaps introduce malfunctioning passage from the added chaos it might succumb to.

TYPES OF ECLIPSE PHOTO

THE STANDARD | THE PARTIAL | THE REACTION SHOT | THE FANCY LENS
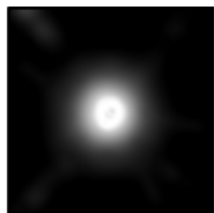
THE FOCUS ISSUES | THE TRAFFIC JAM | THE ASTRONAUT | THE "FRUSTRATEDLY LOOKING UP THE CLOUD SITUATION IN AUSTRALIA FOR 2028"
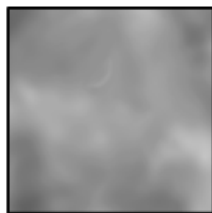
The most rare, top-tier eclipse photo would be the Solar Earth Eclipse, but the Apollo 12 crew's attempt to capture it was marred by camera shake. They said it looked spectacular, though.

Explanation

On the day of this comic's release, a total solar eclipse traversed North America, allowing a substantial portion of the United States to view this phenomenon. Total eclipses in any given area are rare enough and impressive enough that witnessing it was a huge event for many people, both those living in the zone of totality and the many people who traveled specifically to view it. This strip addresses the event through different types of photos that people might take.

The Standard: A photo of the solar eclipse during totality, a typical photo most people might hope to take (examples shown here and here). This photograph captures the Sun totally blocked by the Moon, with a barely visible ring of light around the outside, which comes from its 'atmosphere' and other external features, rather than the solar surface that would normally be visible.

The Partial: A photo of the eclipse in progress, likely approaching totality (example shown here). Another typical photo most viewers take as the eclipse progresses, and the only type of image available to people outside the zone of totality.

The Reaction Shot: During an eclipse, people tend to gather outside in crowds to witness the event in person. Images of people gathering and looking up at the sky capture the human side of this event, and is likely to be

more personal to the person taking the photo (particularly since the people may be their friends and family). This article by Global news shows several reaction pictures such as this and this.

The Fancy Lens: A photo of this type (examples shown here and here), that features conspicuous solar prominences, will almost certainly require a lot more preparation and equipment (the 'fancy lens', a tripod or other mounting, etc). The prominences are dim, compared to the Sun, and usually are visible only when the Sun is completely covered because of contrast issues. Due to the lack of significant atmosphere on the Moon, the hard edge of the similarly-sized Moon can reveal these details whilst obscuring the usually dominant sunlight.

The Focus Issues: People new or unaware of the difficulties of astral photography typically experience challenges focusing their lenses on astral bodies, especially if they are trying to fight against a confused auto-focus. The eclipse is no exception to this, and this type of photo popped up more frequently during this event because more people were taking this fleeting opportunity to take photos of the sky than usual. This article explains some of the tips (such as using a tripod to steady the camera and using manual settings for exposure and focus) to get professional looking pictures of eclipses and shows pictures of an amateur (left) vs a professional (right) picture.

The Traffic Jam: Since the experience of a total eclipse is only available in a specific geographical range, it's

extremely common for people to travel to view them, particularly when this range is near to heavily populated areas (as in this case). The number of people trying to get into a particular area for a particular event naturally causes huge issues of traffic and accommodations. One example is traffic jams, which can become huge and last for many hours. The Daily Gazette reports a number of traffic related slowdowns (photo 1, photo 2) in Schenectady, New York as people return from viewing the eclipse. It states many people spent double the normal time to get to their destination as compared to normal (non post-eclipse) travel. The irony of waiting in traffic for hours in order to see an event lasting several minutes can be frustrating, and an image of the traffic jam may be a bitter way to capture this irony.

The Astronaut: Astronauts on the International Space Station had a particularly unusual view of the solar eclipse, seeing the Moon's shadow on the Earth's surface. Forbes has an article that shows the pictures of the eclipse from NASA and the ISS in orbit 250 miles (400 km) above the Earth.

The "Frustratedly Looking up the Cloud Situation in Australia for 2028": There were clouds over a large portion of the United States and Canada during the April 2024 eclipse. This is a photo similar to the one in the comic, taken in Niagara Falls, Ontario where it was cloudy during the eclipse. For most of North America, this meant that heavy cloud cover blocked their view of the Sun during the eclipse, badly impacting the viewing experience. This was naturally highly undesirable,

particularly those who had planned and traveled to see it. The joke here is that such a person, seeing only clouds during the eclipse, might try to figure out the next time that seeing an eclipse would be possible. There will be a total eclipse passing over Australia and New Zealand in 2028. For someone in the United States, this would require a much more significant trip than the 2024 trip, but someone who missed one eclipse might be willing to go to extremes to see another. The irony is that weather is impossible to accurately predict 4 years in the future, so such a plan would involve the risk of traveling halfway around the world, only for them to more likely than not miss another eclipse due to overcast or cloudy weather.

One common type of eclipse image (albeit from more experienced photographers with photo-editing experience) is the timelapse photo (examples here and here) which Randall does not reference in his comic (although a timelapse could feature photos used in the comic). A timelapse eclipse photo includes multiple exposures of the eclipse at multiple times, often before eclipse totality, during totality and after totality; effectively superimposing the before, during and after shots of the eclipse in a single image.

The title text refers to a photograph taken during the Apollo 12 mission when the Earth came between the spacecraft and the Sun on the journey back home from the Moon. Technically there is a "Solar Earth Eclipse" every night, as the Earth is then between you and the Sun and shades your view of it, but Randall is referring to an incident when Apollo 12 was positioned such that the

spacecraft, Earth, and Sun lined up. The photograph was taken shortly before totality; other pictures as well as video footage during totality were taken, but are of considerably lower quality due to a shaky camera.

#2918: Tick Marks

April 10, 2024

DEADLINE
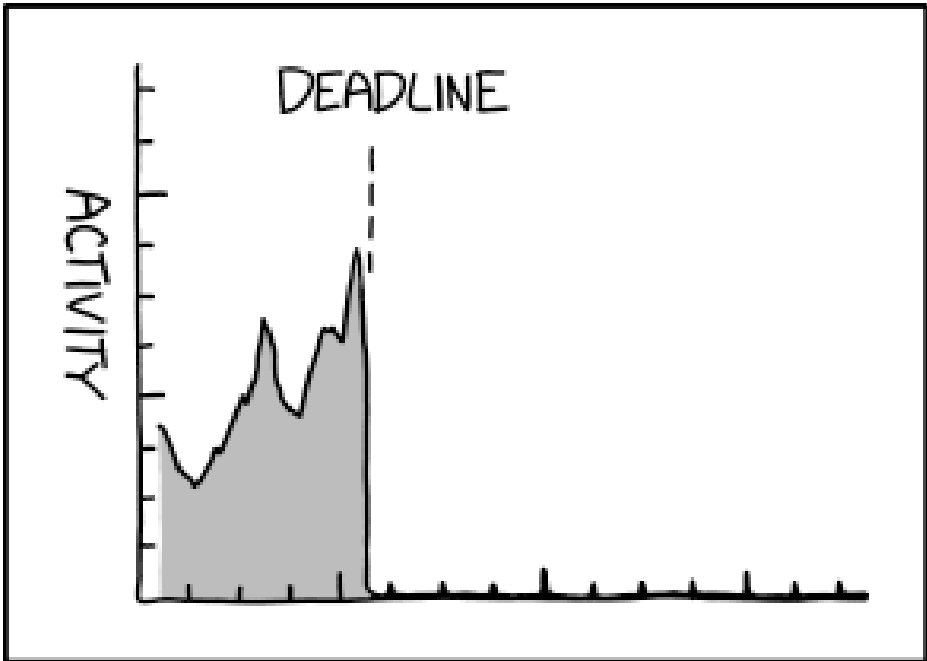
ACTIVITY

IF YOU NEED TO CONCEAL ACTIVITY,
TRY TIMING IT TO HIDE BEHIND THE
TICK MARKS ON THE GRAPH AXIS.

If you're really savvy, you can hide an entire set of illicit transactions by timing them to draw what looks like a graph inset.

Explanation

This comic provides the reader with a suggestion on how to "conceal activity" — specifically, in this case, activity happening after what should have been the deadline for completing it — that is going to be graphed over time, by timing bursts of activity to coincide with the ticks on the time axis. This is assuming that the scale of the time axis is known, that the ticks are placed inside the axis line, and that the "bottom" of the graph is aligned with the line on which the ticks are drawn, rather than the "peak" of the largest tick.

Theoretically, the graphed "activity" would be concealed behind the ticks, meaning anyone reading the graph would perceive activity as having ceased at the deadline, even though it had continued in time-axis-tick-sized bursts afterwards. In practice, this would be extremely difficult to do, since it may be impossible to predict what scale the graph might use and the intervals used for major and minor tick marks. Only if the chart designer used the same, consistent and predictable axis tick marks each time the chart was generated and refreshed, would this technique of hiding data amongst the axis tick marks be feasible. Software such as Microsoft Excel may have automatic axis algorithms which may change the scaling and the position of the tick marks when generating charts. If the "hidden" data and the tick marks didn't align, you would get a Moiré effect, which would likely lead to someone becoming suspicious and discovering the hidden data.

The title text continues with tips on how to make illicit transactions by integrating them in such a manner that makes them appear to be (or merge into) a graph inset, which would contain relevant information to the graph. For this to work convincingly, it would probably have to be a scatter plot or similar, rather than a bar chart or line chart, upon which carefully crafted datapoints could 'draw' a credible facsimile of graphical meta-features. This reference is timely because the comic came out during tax season, a period when many[citation needed] Americans need to find an explanation for illicit transactions or sources of revenue.

Variations (or possibly inversions) of pretending that actual data is part of the graphical framing device have also been previously seen in the form of flags.

#2919: Sitting in a Tree

April 12, 2024
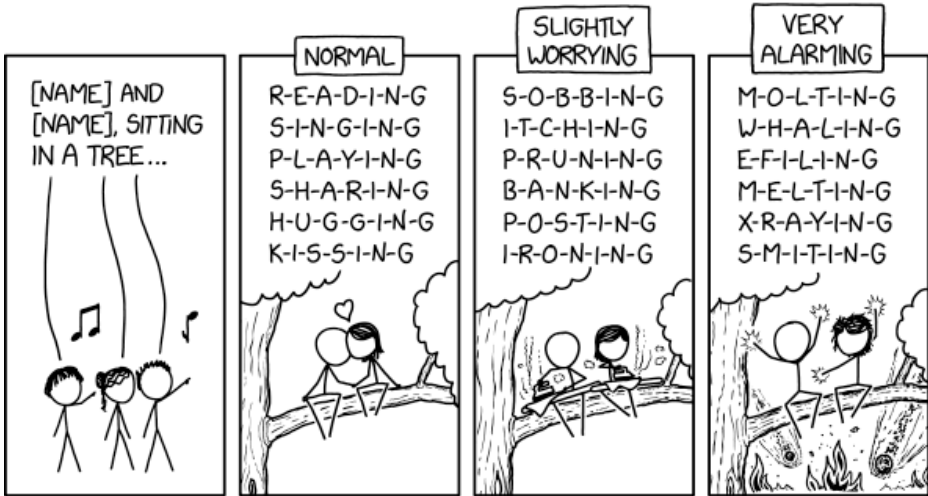
First comes blood / Then we perish / Then comes Death in his Eternity Carriage.

Explanation

"[Name] and [name], sitting in a tree, K-I-S-S-I-N-G" (pronounced as the names of the letters, e.g. "kay eye ess ess eye en gee") is the start of a common US schoolyard taunt to tease others about their alleged romance. As the comic notes, the rhyme can use a range of normal seven-letter present participles of verbs.

Like other schoolyard taunts, the goal may be to elicit a reaction of frustration, anger or embarrassment. It may also just be chanted at a random set of two kids, such as part of a counting-out game.

This comic lists a diverse group of eighteen seven-letter gerunds which Cueball and Megan could be accused of performing in a tree, and organizes them into three categories: Normal, Slightly Worrying and Very Alarming. Each list of gerunds has an illustration of its last one: kissing, ironing and smiting, respectively.

Normal:

- Reading is an activity usually encouraged, which can be performed in a tree without any additional danger.
- Singing is similar to reading, in that it is a good thing (that does not become dangerous by doing it in a tree). However, Jill and Hairy's chanting may disturb Cueball and Megan's singing, or the other way round.
- Playing is what most children are doing when they climb trees.

- Sharing is a good thing. Though it could potentially be hazardous in a tree, due to slightly increased risk of falling while trying to share, it is not a major concern.
- Hugging is a physical sign of affection (romantic or otherwise), which doesn't change much due to the treetop locale.
- Kissing is the activity illustrated in the panel. It is the most normal thing to be sung in the song, as it is the traditional taunt.

Slightly worrying:

- Sobbing is an act of weeping heavily, e.g. due to a setback in one's relationship, or perhaps due to being stuck up a tree.
- Itching is feeling a sensation on one's skin that makes one want to scratch or rub it, and may happen due to mosquito bites or other bugs, or perhaps an allergic reaction to tree bark.
- Pruning is cutting off the branches of a tree, which is very dangerous if one is sitting on said branch.[citation needed]
- Banking is conducting financial business with a bank, or if one works for the financial institution, conducting financial business with a customer cohort. Most banks do not have branches in trees[citation needed] but with suitable equipment, online banking in a tree is quite possible if a little unusual.
- Posting is to publish posts on social media. An antiquated definition is to send mail using a postal

service. This may be worrying due to a perceived addiction to technology.

- Ironing is smoothing clothes with an iron and a flat surface, like an ironing board. This is the activity illustrated in the panel. It should not be performed in a tree, due to safety concerns.

Very alarming:

- Molting is shedding one's skin. Many insects molt in trees, such as cicadas, grasshoppers, and termites. For humans to molt, something would have to be very wrong indeed.

- Whaling is hunting whales, which has been outlawed in the US since the 1980s. Whales aren't usually found in trees.[cetacean needed] And since the letter 'W' is three syllables when sung aloud, this is the only gerund in the comic that doesn't have the standard seven syllables of the traditional taunt.

- E-filing is submitting one's tax returns online, common in the US. This comic was published a few days before the US tax deadline. E-filing could quite reasonably be done from a tree using a laptop or other portable computing device, but is not typically performed by schoolchildren. This may also be a reference to efilism, a philosophy that espouses total destruction of all life on Earth to minimize suffering.

- Melting is turning from a solid state to a liquid state, which is usually fatal.[citation needed]

- X-raying is using X-ray radiation to image someone or

something for medical or security purposes, not normally conducted in trees. With enough radiation, the X-rays could be fatal.

- Smiting is striking down, destroying or killing, often with divine power called from a god. This is the activity illustrated in the panel.

The title text continues the S-M-I-T-I-N-G version of the chant with a parody of the traditional next verses, "...first comes love, then comes marriage, then comes baby in a baby carriage" (which reflects the common social expectations that any kissers might follow the path of). Instead, the parody appears to be a dark prophecy about the grim ramifications of smiting directed by the tree-ensconced kids:

It might indeed be alarming to hear schoolkids singing about their own bloody death from divine judgment, channeled by their tree-ensconced peers. It might not be out of place if the kids are all part of a death cult, and the children in the tree are believed to have the power to direct divine punishment.

The last line may be an allusion to the Emily Dickinson poem "Because I Could Not Stop For Death", which refers both to Death riding in a carriage and eternity. The comic was posted in April, National Poetry Month. Munroe also referenced "Because I Could Not Stop For Death" in 788: The Carriage.

The combination of "Death" from the title text and "E-Filing" is similar to the "Death and Taxes" idiom.

#2920: Survey Marker

April 15, 2024

Panel 1: I LOVE FINDING THESE SURVEY MARKERS. IT'S SOMEHOW REASSURING.

(Survey marker: U.S. GEOLOGICAL SURVEY — ELEVATION ABOVE SEA — 447 FEET — 1941 — BENCH MARK)

Panel 2: I LIKE THAT SOMEONE, SOMEWHERE, KNOWS WHERE THIS SPOT IS.

IF I STAND ON IT, THEY KNOW WHERE *I* AM.

Panel 3: BUT THE NAD83 AND NAVD88 DATUMS ARE GETTING REPLACED SOON. THAT MARKER'S COORDINATES COULD SHIFT BY LIKE 5 FEET.

Panel 4: OH LOOK, IT JUST GOT UPDATED.

HEY! PUT ME BACK!

Fun fact: The standard North American NAD83 coordinate system is misaligned from the actual Earth, off-center by about 7 feet. Someone knows where I am, and I'm in the wrong place.

Explanation

Cueball and Megan have found a survey marker on the ground. Survey markers such as these are used as reference points for the NAD 83 and NAVD 88 geodetic reference systems, and the U.S. National Geodetic Survey has a database storing the coordinates of these markers. However, those two systems are being replaced by the New Datums of 2022 (delayed to 2024-2025), which is primarily based on satellite systems and gravimetric models.

When they update the database in the comic, Cueball's position, both horizontal and vertical, changes to compensate, leaving him panicking in mid-air. In reality, updating a database to change the coordinates of a location would not physically move items at the location.[citation needed] Arguably, if they did, no one would notice much, since everything surrounding them should similarly move simultaneously to its corrected position as well. On the other hand, if the markers were updated and moved relative to each other, and (as the comic suggests) items shifted based to match the new markers, this could mean that objects would be stretched or compressed depending on whether the new markers were closer or further away from each other from their previous positions. However, in the comic, the only things whose position is 'known' (and can therefore be 'corrected') are those that are directly on a marker, hence why this shifting does not seem to apply to Megan (or her phone).

The title text refers to NAD 83 being around 7 feet off. This probably refers to the difference of about 7.2 feet (2.2 m) in the positioning of the centers of the notional Earth ellipsoids used as the basis for NAD 83 and WGS 84. This is also one of Randall's fun facts.

Absurd outcomes from differing survey standards was also the topic of 2888: US Survey Foot.

#2921: Eclipse Path Maps

April 17, 2024

EVERY ECLIPSE PATH MAP

ZONE WHERE TOTALITY
LASTS 1-2 SECONDS

BAY OF
SHIFTING ICE

SHIPWRECK
COVE

DESERT SO HARSH
THEY TRAIN MARS
ASTRONAUTS THERE

SEA OF ROCKY CRAGS
AND MAELSTROMS

[STATE DEPARTMENT
TRAVEL ADVISORY]

ISLE OF PERPETUAL FOG

NICE, SCENIC, ACCESSIBLE
AREA (6 SQUARE MILES,
40,000,000 VISITORS EXPECTED)

TORNADO CAPITAL
OF THE WORLD

AREA WHERE THE ECLIPSE
WILL BE LOW IN THE SKY,
BEHIND THE TORNADOES

Okay, this eclipse will only be visible from the Arctic in February 2063, when the sun is below the horizon, BUT if we get lucky and a gigantic chasm opens in the Earth in just the right spot...

Explanation

A total solar eclipse occurred on April 8, 2024 in North America, nine days before this comic. This comic comments on the fact that most solar eclipses happen on territories not easily reachable by humans, places with weather conditions that make viewing the eclipse less appealing, like cloudy skies (mentioned previously in 2915: Eclipse Clouds and 2917: Types of Eclipse Photo), fog, or tornadoes (also a recurring subject on xkcd), or areas that experience only a short period of totality.

The title text mentions the solar eclipse of February 2063, and claims it will only be visible from the Arctic, though in fact this annular eclipse will traverse through the Indian Ocean. The eclipse in the comic would supposedly happen when the Sun would be below the horizon, which is a contradiction in terms, since an eclipse is only an eclipse from the standpoint of the viewer — it is equivalent to saying that the eclipse is not visible from that location, but is visible from a location over the horizon, at a point that is at the other end of a direct straight line through the Earth that is directed 'down' towards the unrisen Sun and Moon. It then jokingly suggests that a giant chasm could open up between the location being considered and the location from where it would be visible, allowing people to view it. If this did happen, the chasm itself would likely eclipse the eclipse as a spectacle. In most cases, it would also likely cause severely detrimental effects (for example, magma eruptions, tsunamis, etc.), and would therefore

not be considered 'lucky' by most people, despite the small and short-term benefit of being able to view an eclipse from a previously unsuitable location.

Note: The Novaya Zemlya effect can make it possible to observe a solar eclipse when the Sun is below the horizon at the poles during certain weather conditions. Also called a "polar mirage", the effect is when an atmospheric inversion ducts sunlight along the surface of the Earth for distances up to 250 miles (400 km), which would make the Sun appear 5° higher in the sky than it actually is. This appears to be the rare situation where Randall was unaware of an obscure scientific phenomenon that would contribute to a joke.

Possible references to actual eclipses[edit]

- Despite the solar eclipse of April 8, 2024 passing through many populated areas of the United States, many weather forecasts a few days before were pessimistic, predicting significant clouds, and even thunderstorms, along a large majority of the eclipse path. Examples of forecast maps are here and here. Only the very northeast bit of the path had consistently good forecasts, leading to news reports of an all-nighter of traffic jams, which the comic may be alluding to.

- The solar eclipse of August 12, 2026 starts in Siberia, almost touches the North Pole, then touches Greenland, (barely) Iceland, and finally sets in Spain around 8:30pm local. In the relevant part of Siberia, the local time will be very close to midnight and the Sun will still be below the horizon for some. (The Sun will rise around midnight, just before/during/after totality depending on location, and then set after 10pm local.)

In Spain, the length of totality will be significantly shortened due to the shallow angle at which the Sun (and therefore the Moon's shadow) hits the Earth. Notably, this is the next upcoming total solar eclipse as of this comic's publish date.

- The solar eclipse of August 2, 2027 touches the southern edge of Spain and Gibraltar, then proceeds to go through numerous areas known for their political instability.

- The solar eclipse of November 14, 2031 takes place entirely over the Pacific Ocean.

#2922: Pub Trivia

April 19, 2024

WELCOME TO PUB TRIVIA! ROUND ONE IS 10 QUESTIONS:

1. WHICH MEMBER OF BTS HAS A BIRTHDAY THIS YEAR?

2. HOW MANY SIDES DOES A PLATONIC SOLID HAVE?

3. WHAT IS THE SMALLEST LAKE IN THE WORLD?

4. WHICH STEVEN SPIELBERG MOVIE FEATURES MORE SHARK ATTACKS—*JAWS* (1975) OR *LINCOLN* (2012)?

5. HOW MANY PLANETS WERE THERE ORIGINALLY?

6. WHAT NFL PLAYER HAS SCORED THE MOST POINTS OUTSIDE OF A GAME?

7. THE WRIGHT BROTHERS BUILT THE FIRST AIRPLANE. WHO BUILT THE LAST ONE?

8. IS EVERY EVEN NUMBER GREATER THAN 2 THE SUM OF TWO PRIMES?

9. NOT COUNTING CANBERRA, WHAT CITY IS THE CAPITAL OF AUSTRALIA?

10. WHO PLAYED THE DRUMS?

A LOCAL PUB TRIVIA PLACE HIRED ME TO RUN BAD QUIZZES AT COMPETING BARS.

Bonus question: Where is London located? (a) The British Isles (b) Great Britain and Northern Ireland (c) The UK (d) Europe (or 'the EU') (e) Greater London

Explanation

Many pubs have trivia nights, where patrons form teams and compete to answer questions about a range of topics. The typical goal for trivia games is that they be challenging, yet possible, and so questions with answers that are too difficult or too easy generally make for a poor game. In addition, it's usually preferable that questions are clearly worded with a single, objective answer, so as to avoid disputes about which answers are correct.

Cueball has apparently been hired by one bar to infiltrate other bars' quiz nights and ask particularly bad questions. The implication is that this will make the games unpleasant, in the hopes that people will leave, and possibly go to the bar that hired Cueball.

Cueball uses a variety of strategies to write bad questions, including questions that are trivial (where the answer is painfully obvious), unanswerable (either because there is no answer or because the answer is unknown), ambiguously worded or arguable.

Many of his questions could be altered slightly to make them more reasonable for such a game, but that would defeat Cueball's purpose.

#2923: Scary Triangles

April 22, 2024
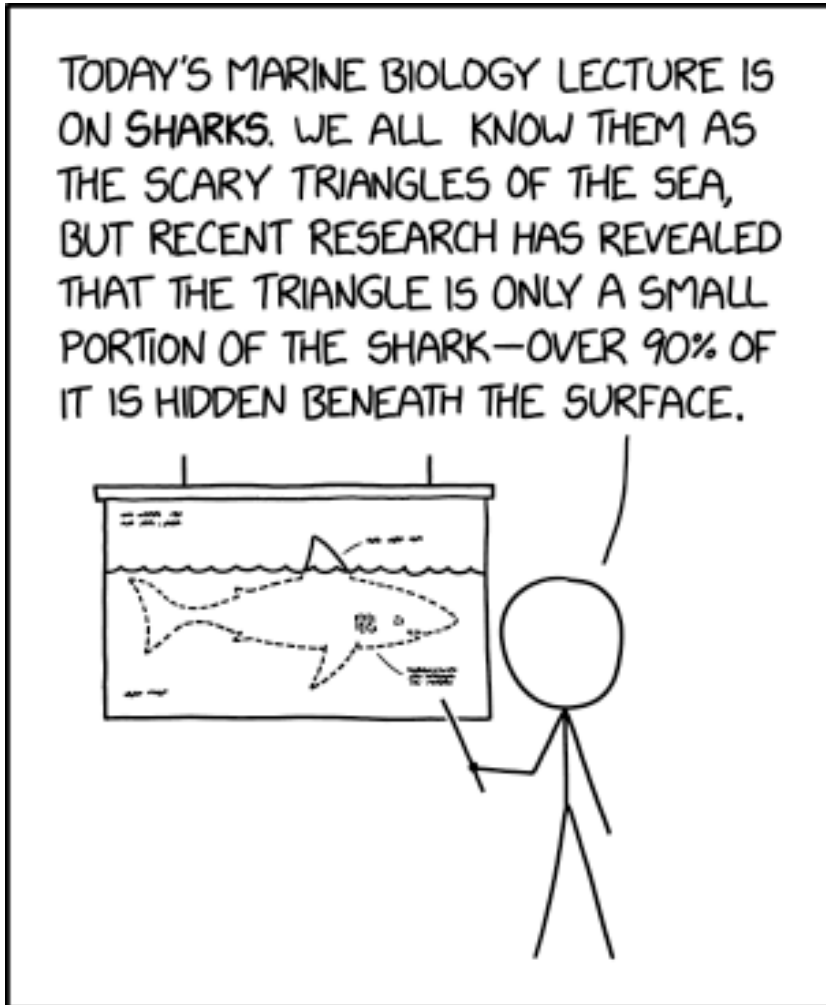
Concealed mostly beneath the surface, sharks are the icebergs of the sea.

Explanation

Cueball is giving a marine biology lecture about sharks and seems to have mixed up icebergs with the topic.

In pop culture, sharks will often approach prey or people with only their front dorsal fin visible, which looks like a triangle, above the water. As far as its usual marine prey is concerned, this is inaccurate, as most sharks will attack from below to keep the element of surprise. From the human perspective, we're just more used to (and capable of) seeing the surface of the sea so, most of the time, if we actually know that there is a shark in the area then it's because it is currently swimming close enough to the surface to have its dorsal fin conspicuously sticking into the air - whether or not it is a hunting shark, a dangerous shark or even an actual shark. Another contributing factor is the movie Jaws, in which, due to problems with the animatronic shark, most scenes where filmed with the shark mostly or completely hidden.

In the comic the joke is that Cueball reveals that marine biologists have only recently learned that the triangle is only a small part of a shark. Until this revelation people were only aware of the visible portion, and the fact that death and injury often occurred when they arrive, causing them to be known as 'scary triangles'. Finally the community has learned that more than 90% (i.e. the rest of the shark's body) is hidden beneath the surface. (In most, if not all, cases it would actually be significantly more than 90%.)

The 90% is borrowed from an often cited factoid about icebergs: that 90% of their volume is underwater (see also 2829: Iceberg Efficiency). This follows from the relative densities of ice and water: the fraction under water is the density of the ice divided by the density of the water. For pure ice just below freezing in pure water just above freezing this would be 0.92 kg/L / 1 kg/L = 92%. However sea water has a density of 1.03 kg/L, leading to 89%. In reality icebergs are made of compressed snow (which has a lower density) and may be filled with air cavities, leading to lower densities.

Having learned that a similar fact is true of sharks, Cueball has drawn a dotted outline of the shark's body, equivalent to that often depicted in diagrams of icebergs, beneath the scary triangular fin, to show what a shark looks like under the surface. Cueball's enhanced analysis has so far failed to identify some of the even more scary triangles that more often stay below water, and would be experienced proportionately more in actual attack situations, also leaving critical leaky holes in the body.

The title text continues the joke explicitly, saying that sharks are the "icebergs of the sea." However, icebergs are already the icebergs of the sea.[citation needed] A better name would be "icebergs in the animal kingdom".

#2924: Pendulum Types

April 24, 2024

SIMPLE PENDULUM	DOUBLE PENDULUM	INVERTED PENDULUM	NIGHTMARE PENDULUM
• PERIODIC	• APERIODIC	• FINELY BALANCED	• FORBIDDEN
• STABLE	• CHAOTIC	• UNSTABLE	• UNPHYSICAL
• USEFUL FOR TIMEKEEPING	• MODERATELY CURSED	• BECOMES STABLE WHEN VIBRATED	• SUMMONS MAXWELL'S DEMON

The creepy fingers that grow from a vibrating cornstarch-water mix can be modeled as a chain of inverted vertical pendulums (DOI:10.1039/c4sm00265b) and are believed to be the fingers of Maxwell's Demon trying to push through into our universe.

Explanation

This comic shows and describes several pendulums. The first three are actual physics models, while the last one is made up for absurdity. This is a recurring format of xkcd comics, as shown in 2289: Scenario 4.

The inverted pendulum consists of a simple pendulum that is placed upside down, with some powered apparatus underneath vibrating it vertically to keep it upwards. If left unpowered it will fall, hence the "unstable" part. The comic appears to depict Kapitza's pendulum. See a video demonstration by Harvard Natural Sciences or an interactive simulation from myphysicslab or mathigon.

The nightmare pendulum appears to be an inverted double pendulum on a vibrating base, with an additional uninverted pendulum swinging within its much more substantial weight (which is also adorned with grawlixes). The comic claims that this pendulum summons Maxwell's demon, jokingly implying that Maxwell's demon is an actual entity. In fact, Maxwell's demon is a thought experiment in which a being - the demon - is posted at a tiny door between two gas vessels. It lets only slow-moving (cold) gas molecules move through the door in one direction, and only fast-moving (hot) ones in the other direction. One vessel gradually becomes hot and the other cold, violating the second law of thermodynamics. An actual machine doing that would require at least enough energy - in the form of

information - so that no violation took place, but the thought experiment has stimulated much discussion since it was first proposed by James Clerk Maxwell in 1867.

The title text continues this joke explicitly, by referencing a real paper titled Vibro-levitation and inverted pendulum: parametric resonance in vibrating droplets and soft materials and implying that the paper ties the "creepy fingers" produced in this way to Maxwell's demon. The paper only actually suggests that the phenomenon is related to inverted pendulum dynamics. This gives a humorous example for the abuse of citations. Technically, the cited reference only supports the claim immediately before it, that the behavior of a cornstarch-water mix (also known as oobleck) can be modeled as inverted pendulums. But by proximity the reference also seems to support the part about Maxwell's demon. The illusion is helped by the description of the cornstarch as creepy, which is added in the beginning without any visible separation from the actual content of the citation.
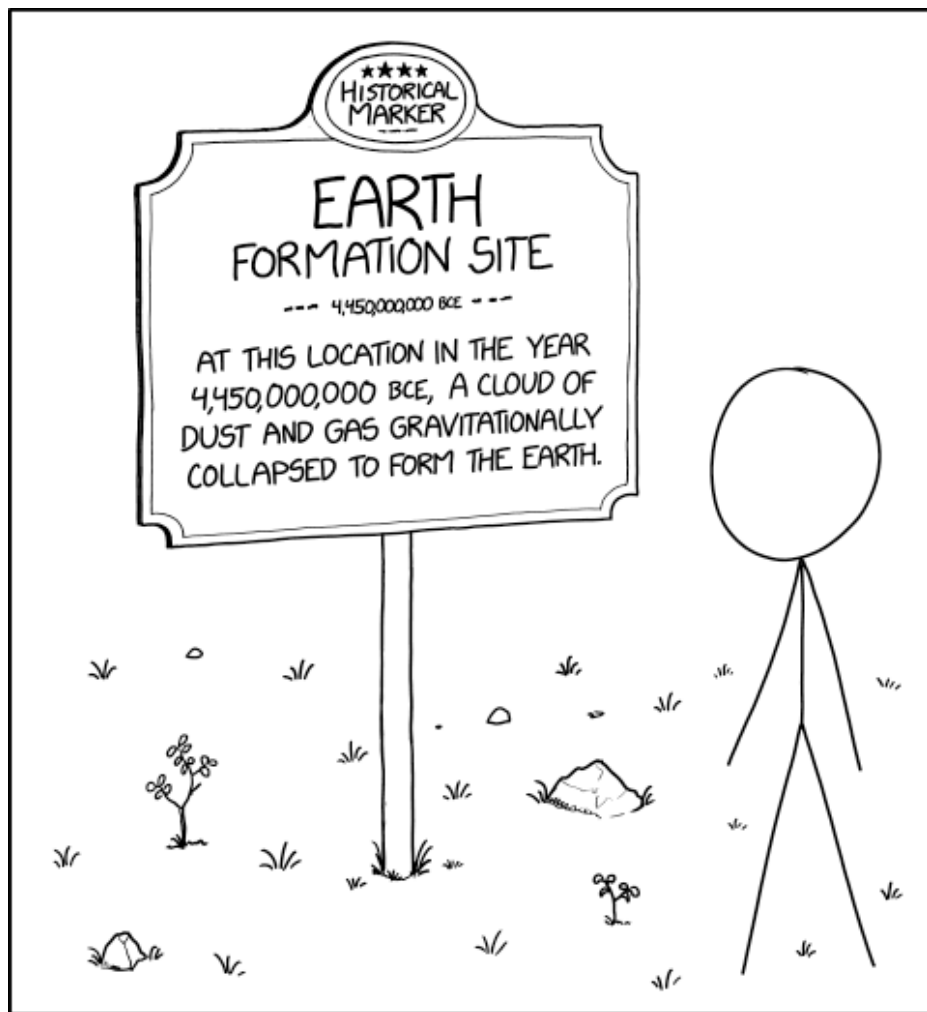
It's not far from the sign marking the exact latitude and longitude of the Earth's core.

Explanation

Cueball reads an historical marker celebrating the formation of the Earth. As with most historical markers, it claims to rest on the exact spot of the event, that the Earth formed in this specific location. It also specifies the Earth's formation to the precise year 4.45 billion (4,450 million) BCE.

The absurdity of the sign is threefold:

#1: The Earth did not form on its surface

First, the Earth formed at its center, not anywhere on its surface, so an "Earth formed here" sign on the surface is amusingly incorrect.

One may argue that technically the sign is above the right spot, just as every location on Earth is above the right spot. However, the sign refers to "this location," not to a spot underground.

If an omniscient observer wanted to mark the spot in space where the Earth started forming, they would need an historical marker floating in space, not on the surface of the (moving) Earth. That's due to the Sun's 225-million year long orbit around the center of the Milky Way galaxy and the movement of the galaxy itself through space relative to other objects.

#2: The precise year of the Earth's formation is not knowable

Secondly, specifying a single year of formation BCE (Before the Common Era) is an amusingly precise choice. It takes tens or hundreds of millions of years for a planet to form. Picking a year would require some specific definition of when a gradually-coalescing mass of proto-planet dust and gas could be considered a planet, as well as the impossible ability to determine when that mass met the definition.

If the precise year was knowable, the probability of the number actually ending in seven consecutive zeros would be on the order of one-in-ten-million.

The topic of what precisely makes a planet — related to the 2006 redefinition of a planet and the subsequent reclassification of Pluto from the solar system's ninth planet to a dwarf planet — has been covered before in 473: Still Raw and referenced in other XKCD comics.

There is some poetry in the idea that there was a precise year, some 4.45 billion years ago, that was the first true year, the first Earth orbit around the sun. By definition, the Earth is the same age as the number of Earth orbits that have ever taken place.

Note: The date shown for the formation of the Earth, 4.45 billion years ago, also differs from the commonly accepted date, 4.54 (±0.05) billion years. The difference lies in the transposition of two digits, 5 and 4, potentially a mistake, as is common in historical markers.

#3: Historical markers typically refer to events within the

past several centuries

Historical markers are placed at precise locations where historical, religious, and even mythological events are believed to have happened — such as where battles have been fought, or where famous people resided or accomplished something. Typically these signs refer to more recent events.

Scientific inaccuracies

Contrary to what the comic suggests, the current scientific consensus is that the Earth did not form from a collapsing cloud of dust and gas. While the mechanism of the Earth's formation is an open area of research, the general idea is that first, the Sun formed from a collapsing cloud of dust and gas. The remaining dust and gas formed a disk around the Sun called the Sun's protoplanetary disk. From this disk, the planets formed. There is currently no consensus on the details of how this happened. But roughly speaking, dust particles in the Sun's protoplanetary disk collide and stick together until the resulting body is massive enough to slowly accrete matter through gravitation. So while the Sun formed from a collapsing cloud of dust and gas, the Earth did not.

Further reading: E.g. Pebble accretion, Streaming instability

The title text

The title text refers to the 'exact latitude and longitude of

the Earth's core,' Of course, since the lat-long geographic coordinate system is used for locating places on the surface on the Earth, the center of the Earth does not have latitude and longitude.

Also, a historical marker referring to the Earth's core could be placed anywhere on the surface, and its specific location in the real world wouldn't mean anything; just as before, every spot on Earth is above the right spot.
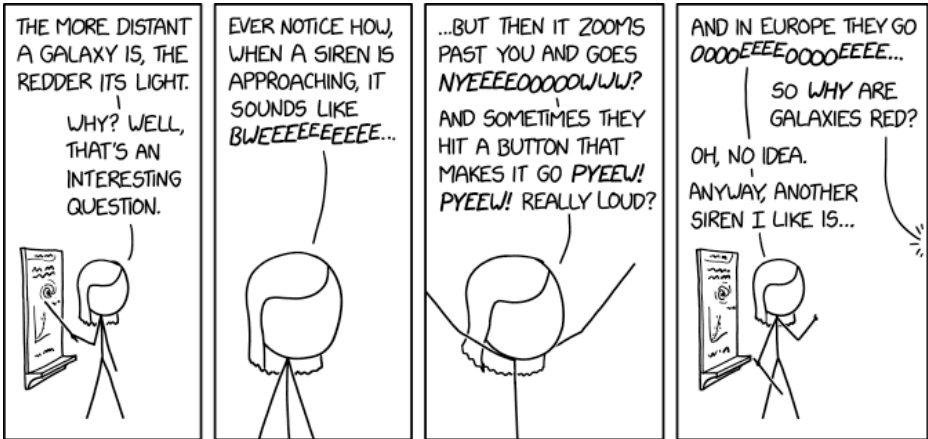
Examples of similar historical marker signs:

• Kenya Equator latitude
• Arctic Circle latitude
• Prime Meridian longitude
• Highest Point
• Lowest Point

Analysis

The comic and its title text are actually inverse jokes of each other: The historical marker in the comic assigns an attribute of the Earth's center (the site of formation) to a spot on its surface, while the historical marker mentioned in the title text assigns an attribute of surface locations (latitude and longitude) to the Earth's center.

#2926: Doppler Effect

April 29, 2024

THE MORE DISTANT A GALAXY IS, THE REDDER ITS LIGHT.

WHY? WELL, THAT'S AN INTERESTING QUESTION.

EVER NOTICE HOW, WHEN A SIREN IS APPROACHING, IT SOUNDS LIKE BWEEEEEEEEEE...

...BUT THEN IT ZOOMS PAST YOU AND GOES NYEEEEOOOOOWWW?

AND SOMETIMES THEY HIT A BUTTON THAT MAKES IT GO PYEEW! PYEEW! REALLY LOUD?

AND IN EUROPE THEY GO OOOOEEEEOOOOEEEE...

SO WHY ARE GALAXIES RED?

OH, NO IDEA. ANYWAY, ANOTHER SIREN I LIKE IS...

The Doppler effect is a mysterious wavelength-shifting phenomenon which seems to primarily affect sirens, which is why the emoji is red.

Explanation

Miss Lenhart is teaching an astronomy class about the concept of redshift in the light from distant galaxies. She states that why this occurs is an interesting question, then follows this by talking about the Doppler effect of sirens. While sirens are commonly used as an example of the concept of the Doppler shift, and is hence relevant to the preceding topic, Miss Lenhart appears to have raised it for a completely unrelated purpose - she simply has a special interest in sirens. This becomes apparent as her explanation quickly veers away from the preceding topic, similarly to 1519: Venus, or due to a form of topical monomania similar to that which Hairbun exhibited in 1610: Fire Ants. In 1158: Rubber Sheet, Beret Guy similarly subverts expectations of using a scenario as a common analogy to a scientific concept, when he is in fact enjoying it for its own sake.

Different emergency vehicles may have different siren tones, and many have different tones on the same vehicle, which they can switch between for different circumstances, such as long NYEEEOOOWWW to alert people at a distance and short PYEEW PYEEW when they are closer to drivers, as for example when crossing an intersection.

In the second and third panels, Miss Lenhart talks about the strange change in perceived noise sirens (and cars) make when they pass you. The usual explanation of Doppler effect is that the source of the sound waves is

moving and the wave can sound different depending on whether the source is coming towards you or away from you (for details/explanation see the Doppler effect in Wikipedia).

Redshift is the same concept applied to wavelengths of light. Red has a longer wavelength than blue, so light-emitting objects get redder when they move away from us and bluer when they move toward us. We usually talk about redshift and not blueshift because while stars in our galaxy can move in any direction relative to us, most other galaxies are moving away from us. The fact that more distant galaxies are moving away quicker the farther away they are shows that the universe is expanding.

Unlike the usual explanation of redshift as equivalent to the Doppler effect for sirens, a major component of the redshift of light from distant galaxies is due to the expansion of space in between us and the light source. This effect is not an important component of the Doppler shift for sirens.[citation needed] Redshift has been mentioned multiple times before, including in 2764: Cosmological Nostalgia Content and 2853: Redshift.

The title text claims that the Doppler effect particularly affects sirens. This isn't actually true, but it may seem like it because people hear Doppler shifts for sirens more than for other sounds. Sirens tend to employ predictable tone(s), which people who aren't totally tone deaf would have experienced as a shift in pitch from a passing

vehicle's siren, whereas something equally subject to Doppler shift like engine noise could also change pitch according to differences of speed and gearing. Then the text claims that the emoji for sirens is red because they're associated with redshift. Actually, the emoji is a picture of the rotating light on top of emergency vehicles; these tend to be used in conjunction with sirens, and they're red because this color typically signifies danger or warning (though, in fact, blue lights used with sirens are also common).

#2927: Alphabetical Cartogram

May 01, 2024

A MORE FAIR MAP

INSTEAD OF GIVING MORE AREA TO LARGER STATES, THIS MAP IMPROVES FAIRNESS BY SIZING THE STATES ALPHABETICALLY.
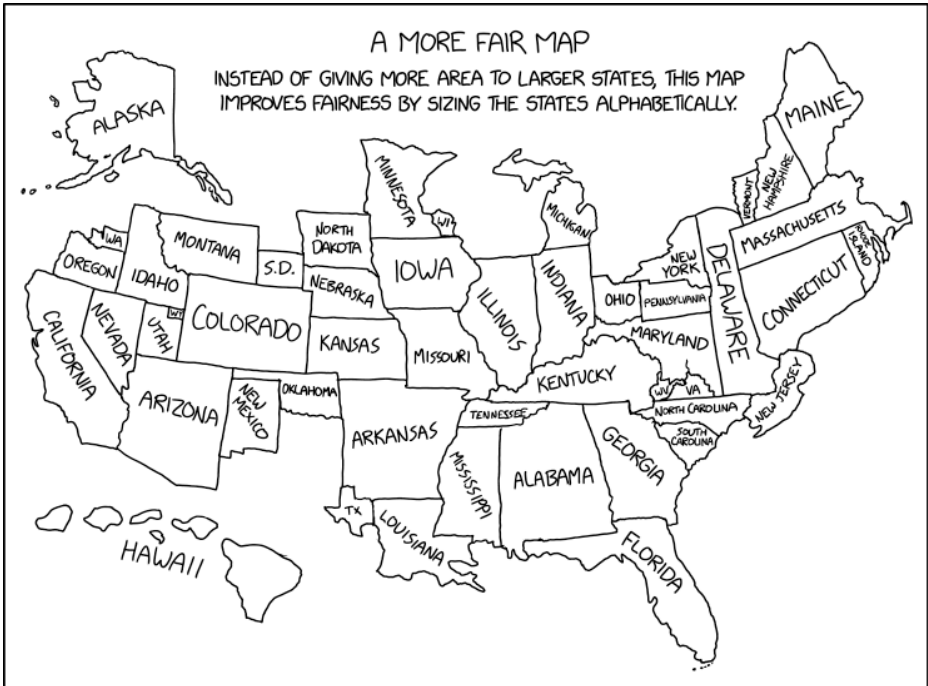
Poor Weeoming.

Explanation

This comic shows a map of the United States, with every state resized based on where it appears in an alphabetical list of states. Hence Alabama is the largest state and Wyoming is the smallest. The joke is that the comic purports to "be more fair". But there's nothing fair or unfair about sizing states by alphabetical order, whether or not it is 'fair' in the first place to have states being shown as bigger or smaller merely because of raw geographical fact (and perhaps a little bit of cartographic bias).

Wyoming shrank the most proportionally in geographical size, while Delaware grew the most. Compared to a ranking of US states by area, Texas dropped the most (41 places), while Delaware and Connecticut rose the most (also 41 places). South Carolina and Vermont did not change rank.

This coincides with a recent study from the University of Michigan showing that the alphabetical order of surnames leads to differences in grading.

With 2024 being an election year in the United States, this comic may be a spoof on electoral cartograms, which resize the states based on their number of electoral votes (roughly the same as resizing them based on population).

The title text creates a portmanteau of the words "wee," which means "little," and "Wyoming," making fun of

how small it is on this map, since Wyoming appears last on the alphabetical list of states, it could also refer to the previous comic, which discussed siren noises. It may also refer to the common mispronunciation of the name, or a deliberate renaming to push it higher alphabetically.

Bias resulting from alphabetical order was also the topic of 2789: Making Plans.

It should be noted that the resizing is not done perfectly in the drawing. For example, Vermont appears slightly larger than Texas, and Idaho appears smaller than Missouri. The map strikes a balance between actually making the sizes of the states correspond to their alphabetical order, keeping the shapes of the states correct, and making the "lower 48" states fit together contiguously. The shapes of many states are significantly warped, such as Maryland, Delaware, and New York (which is lacking Long Island).

The table below ranks the states according to their actual size, their alphabetical order, and their approximate size as they are drawn in the comic.

Table of states[edit]

#2928: Software Testing Day
May 03, 2024

SO, DO YOU AND THE OTHER QA ENGINEERS HAVE ANY FUN PLANS FOR THE HOLIDAY?

YEAH, ASSUMING THE SCHEDULING SYSTEM DOESN'T CRASH.
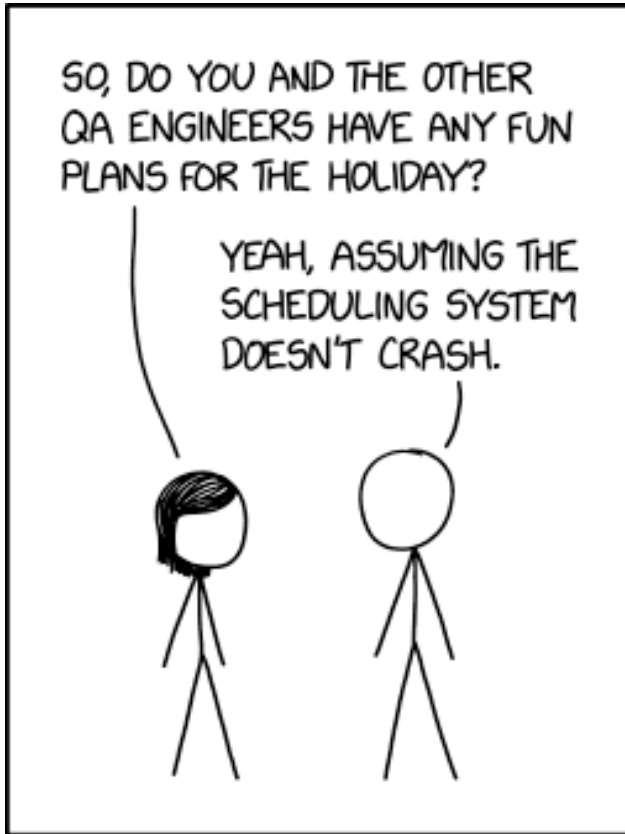
SOFTWARE TESTING DAY IS A HOLIDAY CELEBRATED EVERY -1 YEARS ON JANUARY 0TH AT 25:71 PM.

The company tried to document how often employees were celebrating Software Testing Day, but their recordkeeping system kept mysteriously crashing.

Explanation

Quality Assurance (QA) engineers are responsible for ensuring the quality of some product through the use of testing. In software, this process often involves entering bizarre and/or nonsense inputs in an attempt to break the software. Cueball, a QA engineer in this case, expresses concern that the scheduling system might crash. This could either be because as a QA engineer he is concerned about crashes in general, or that as a system used by QA engineers it likely has a lot of weird/invalid values that could cause a crash.

For example, here it seems that Software Testing Day, a day likely celebrated by QA engineers, takes place every −1 years on January 0th at 25:71 PM. That statement is nonsensical in the following ways:

- The frequency of a recurring event is always expressed as a positive amount of time, so a negative value like "every −1 years" does not make sense. Negative values are an often-overlooked edge case in software, as they are valid numeric values that the computer will happily accept and work with unless specifically told not to. Depending on what the software is designed to do, this could result in unexpected behavior that could produce nonsensical results or crash the system. Under some circumstances, one piece of code can interpret a value as a small negative number, while another piece of code interprets the same value as a very large positive number. A variable that one section interprets as −1

might be interpreted elsewhere as 255, 65535, 4294967295, or even more, unless the software is either very strongly-typed (so as to actively prevent any casual attempt to change the understood context and value of data) or consistently weakly-typed throughout (the user does not normally define the type, automatic data-typing internalises the understanding (and any conversion) for anything the user does not deliberately make abstract for their own purposes).

- The first day of the month is the 1st, not the 0th. (There is an entire category of bugs/errors which result from numbering systems being mistaken for starting with 0 instead of 1, or vice versa.)

- There are (in most cases) only 24 hours in a day, so "25" is (in most cases) too large, and even where there is a switch from Daylight Saving Time, clocks simply repeat the hour before midnight, so the numbers above 24 hours are not displayed, even if using the 24-hour notation.

 In addition, the "PM" suggests that it is a 12-hour time, so the expected range of values for the hour is 1 to 12, making the "25" even more nonsensical.

- There are only 60 minutes in an hour, so "71" is too large for a normally anticipated minute value.

Apparently, though this date is nonsensical, the QA engineers have decided to make this date a celebration day. Probably since, as expressed in the comic, the software for keeping track of the date has crashed. Another interpretation of this comic could be how

software always crashes in one form or another when being tested, and thus the nonsensical date implies that successful runs of software is never celebrated.

All numerical values are out of range, suggesting that a QA engineer picked this date to test the scheduling system. If the date were to be made sense through under/overflow, it would result on January 1st at 14:11 (2:11 PM). And the -1 year interval could be interpreted to mean it happens every year (perhaps with the annual events being numbered backwards). Alternatively, an attempt to enter these numbers might be rejected as invalid, forcing the user to enter a properly formatted date and time. Both "January" and "PM" are acceptable values; because these two items tend to be selected from predetermined lists since they have an extremely limited number of possible values, it's rarely possible to enter an invalid value for either of these fields.

The title text suggests that the recordkeeping system used to see how often employees celebrated Software Testing Day kept crashing, possibly due to the employees purposefully inputting nonsensical dates or a date that occurred prior to the previous celebration. QA engineers may have semi-accidentally crashed the system by testing it, or deliberately crashed it to disguise the frequency of their days off.

In real life, such invalid dates would be rejected or coerced to be valid dates. Failing to account for invalid dates may result in errors, sometimes catastrophic, such as the February 29, 2012 Microsoft Azure outage caused

by the server trying to generate a certificate valid until February 29, 2013, a date that does not exist as 2013 being a non-leap year.

Treatment of invalid dates varies by the chosen programming language and date-time library. Javascript, for example, would coerce January 0th into December 31st, and 25 o'clock into 1 o'clock the following day. While there is no way to directly create a Javascript Date object using 12-hour notation (because that requires text parsing, and the validation of the text input would just result in an invalid date), the following code snippet represents how far this correction can be taken advantage of:

An event happening every −1 years is equivalent to one that happens every year, but the numbers are reversed; i.e. if this year hosts the 1st Software Testing Day, next year will host the 0th Software Testing Day. This is expected to cause issues in software that assumes that the 2nd Software Testing Day will occur after the 1st Software Testing Day, an assumption that time only moves in one direction that may or may not be reasonable.

The holiday may be due to the claim of "we really can't do anything else, during this automated process", using the same sort of logic as 303: Compiling justified for the programming team. Albeit that here we explicitly learn that a failure behind the scenes will cancel the 'sanctioned' pausing/idling-away of contracted work hours, much as a notable compilation/build error would

interupt the others' few minutes of office sports.

Unusual date-time notation in real life[edit]

- Seconds usually go from 0 to 59. However, when a leap second is added, December 31st, 23:59:59 UTC is followed by 23:59:60 (11:59:60 PM) before starting the new year.

- "24:00" can be used to unambiguously state the closing midnight of a given date. i.e. the same as "00:00" upon the next, but without the ambiguity as to which 'midnight' bookending of the given date it might refer to, e.g. for deadlines.

  It can be generally used to simplify the understanding of how much time is encompassed by a period starting at a pre-midnight time and ending at a post-midnight one.

- Japan, in particular, uses hour numbers greater than 24 to express times past midnight but before sunrise. For example, 25:00 on a Friday is the same time as 1:00 the following Saturday. This is mainly used to express the starting times of midnight TV programming and the closing times of bars and other establishments open late at night. The hours usually go up to 27, but numbers up to 30 (6AM of the following day) are also sometimes seen. It allows the timepoint to 'belong' to the normal working day that precedes it, rather than setting it prior to the normally expected start of business for the day after (especially when that involved weekends).

#2929: Good and Bad Ideas

May 06, 2024
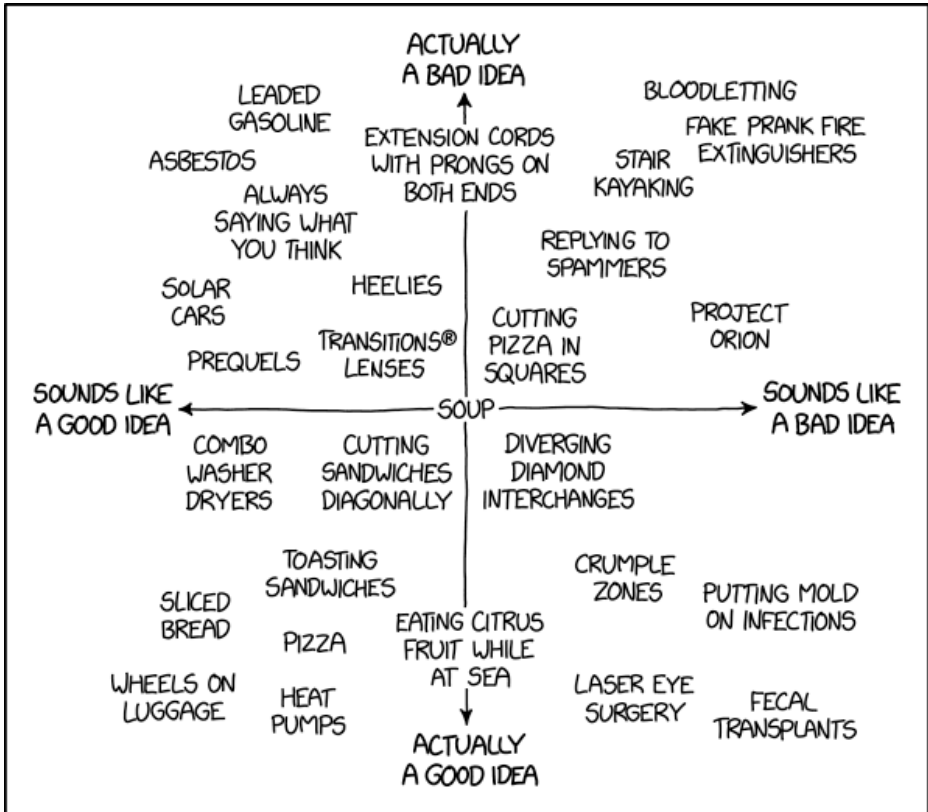
While it seemed like a fun prank at the time, I realize my prank fire extinguishers full of leaded gasoline were a mistake.

Explanation

This is a scatter plot comparing how good an idea sounds to how good the idea is. For example, leaded gasoline sounded like a good idea due to its anti-knocking effects, but is a bad idea due to lead toxicity. Fake prank fire extinguishers both sound bad and are bad, as they can make a dangerous situation worse. Putting mold on infections sounds like a bad idea, but some molds, like ones containing penicillin, have helpful antibiotic effects.

The title text combines leaded gasoline and a fake prank fire extinguisher into something worse than either. The fire extinguisher is fake and releases flammable material onto the fire, and there is additional lead toxicity.

Table of the entries[edit]

#2930: Google Solar Cycle

May 08, 2024

GOOGLE TRENDS SEARCH
TRAFFIC FOR "SOLAR FLARE"

|← —— 11 YEARS —— →|

2005   2010   2015   2020
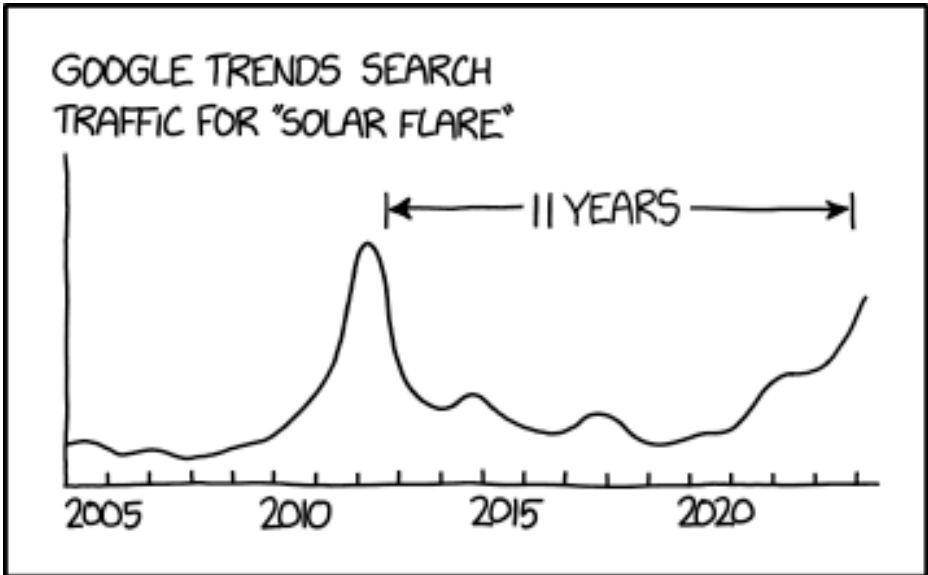
I LIKE THAT GOOGLE HAS EXISTED ALMOST
LONG ENOUGH FOR US TO OBSERVE THE
SOLAR CYCLE USING GOOGLE TRENDS.

From Google Trends, it looks like the lag between people Googling cocktail recipes and 'hangover cure' is 14 hours.

Explanation

Solar flares appear on the Sun's surface in different numbers at different times. A solar cycle is the amount of time that elapses between times of maximum (or minimum) solar flare activity. This period is approximately 11 years.

Solar flares can generate interest, and 'news' stories at times of high activity, because they can sometimes cause aurorae, as well as power outages and other similar issues. Hence people will be more aware of them, and search for "solar flares" on Google to learn more about them. This trend somewhat matches the solar cycle since people will be more interested/concerned about solar flares during the times they are abundant and search for them more often. Randall notes that Google has existed for long enough to see the trend in searches for "solar flare" over a full solar cycle.

The title text comments that people usually Google "hangover cure" 14 hours after they search for cocktail recipes. This suggests that people decide they want cocktails, look for ways to make cocktails, make (and presumably drink) the cocktails, wake up with a hangover and look for ways to get rid of the hangover. Google trends does indeed suggest that there is roughly a 14-hour difference in peaks between these searches. However this does not mean (as the title text implies) that the people searching for cocktail recipes are the same people that are searching for hangover cures later. It may

represent the (not unreasonable) assumption that people who are exploring the idea of cocktails (for themselves or others) generally start to do so from the early evening onward, whilst those who find themselves freshly under the weather (not just from cocktail consumption) are likely to be finally provoked to look up a solution from around mid-morning.

One can illustrate the pitfalls of assuming such causation by substituting "chicken nuggets" for "cocktail recipe" which shows a very similar relationship. Chicken nuggets are not known to cause hangovers.[citation needed]

Looked at another way, there is a 10-hour 'lag' from searching for "hangover cure" to searching for "cocktail recipe"; this does not imply that having a hangover is causing people to be interested in drinking cocktails! (Though they may lead to chicken nuggets.)

Another very important problem with looking at scales of less than a day is that the Earth has 38 time zones, and people drink cocktails and wake up all the time around the world. Since everyone is searching the same Google, it is impossible to deduce anything on a daily basis by looking at global data. It is possible to see only searches from a particular country, but even then, in the case of the US there are several hours difference from east to west that may smear out any such direct observations. This also applies to other countries/regions, being potentially at its most extreme in Russia. This might be moot if the data is preprocessed to 'local' time, although the opposite issue might arise in a case such as Chinese

data (though any examination of Google Trends for China may not be fruitful).

The sunspot cycle was 'explained' in 2725: Sunspot Cycle.

#2931: Chasing

May 10, 2024
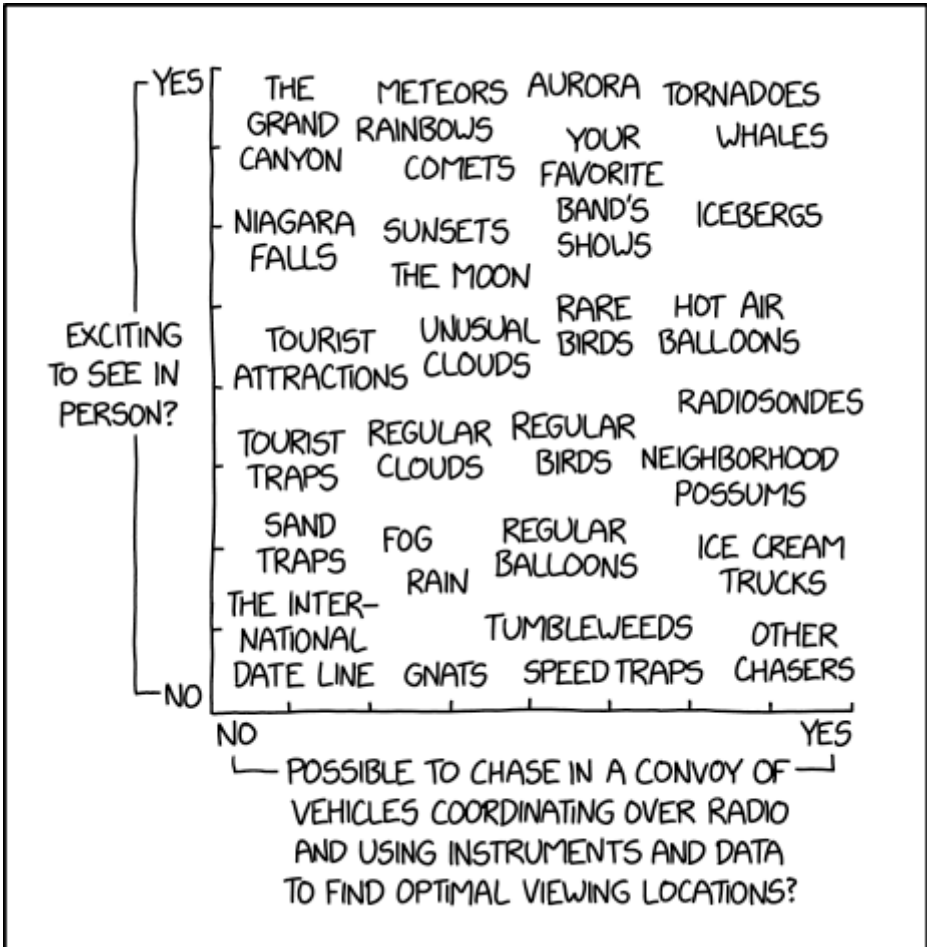
Certain hybrid events can only happen in certain locations where all the conditions are present; chasers flock to the area in and around Kansas known as tumbleweed-colliding-with-possum alley.

Explanation

This comic is a scatter plot comparing how exciting it is to see various things with how possible it is to chase them using a convoy of coordinated vehicles.

The least chasable are stationary places like the Grand Canyon or International Date Line. It makes no sense to chase them because they don't move around, you simply go to their known locations. At the other end of the chasability spectrum are animals that move around rapidly, and fleeting astronomical and atmospherical phenomena like clouds, meteors and aurora. However, some of these are difficult to chase because they're small and hard to detect from a moving vehicle, e.g. gnats.

In the top-right position of most chasable and most exciting, tornadoes have a community of 'chasers' who attempt to predict their appearance and get as close to them as possible, which was the subject of a 1996 film, for which a sequel was due to be released shortly after this comic. A major tornado outbreak had also taken place immediately preceding the comic's publication.

The title text suggests that combining some of these things into a single event would multiply the excitement derived from them. This makes sense on the surface, as the rarity value of the resulting event would be high, so even two relatively mundane events could, when combined, produce an interesting outcome. However, it somewhat undermines this by suggesting that, in this

particular location, the event in question (possums being hit by passing tumbleweeds) is relatively routine.

#2932: Driving PSA

May 13, 2024
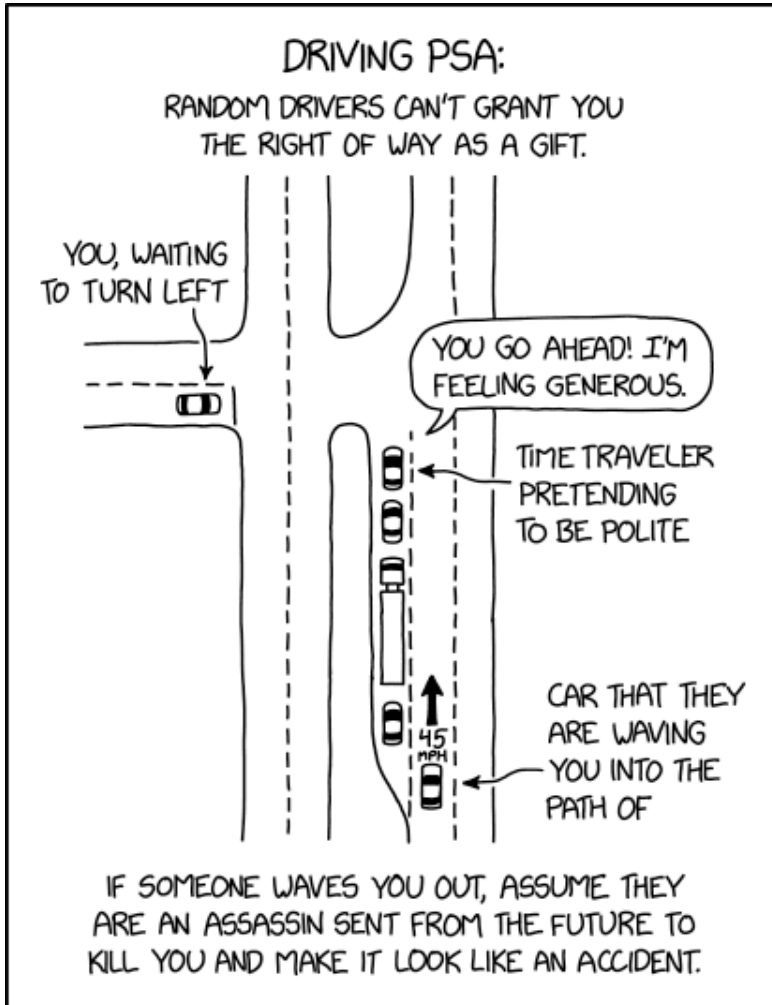
This PSA brought to you by several would-be assassins who tried to wave me in front of speeding cars in the last month and who will have to try harder next time.

Explanation

A PSA is a Public Service Announcement. Some drivers, when having priority by the rules of the road (termed "right of way" in US legal statutes), will let others take it before them. However, yielding the right of way when it is not required does not legally grant the other driver the right of way -- they may still be required to yield to other vehicles on the road. (Hence the title of the PSA: "Random drivers can't grant you the right of way as a gift.")

At a 4-way stop, giving another driver the right of way is usually safe and courteous, but in other cases it can be dangerous. This comic is saying that people who exhibit this behavior dangerously can be assumed to be Terminator-style assassins, sent to kill you by sending you into contention with other traffic to make it look like an accident, and thereby prevent some future act on your part that is not to their liking.

In this comic, the deferential driver is holding up a queue of vehicles (including a large tractor-trailer truck) that is obscuring the immediate view of oncoming traffic. Instead of simply turning left and reducing the queue, they are waving Randall's car into that traffic, perhaps because they forgot that the other lanes have priority over the crossing driver. The effect could be to wave him through right into the path of another car traveling at full speed — a clever way for a time-traveling assassin to take down one's target without arousing suspicion.

Not pulling into traffic when your view is obstructed is good advice, and Randall's comical exaggeration may make the advice more memorable. Always check for yourself that your way is clear, and if your view is blocked, sit tight.

However, Randall seems to be assuming that the waving gesture can only ever mean one thing: Pull all the way into traffic. It may be that a "waving out" gesture is intended to give the waiting car a chance to turn into the median strip (see details below). Viewing courteous behavior as conclusive evidence of a temporal assassination conspiracy is humorously ego-centric and improbable.

The title text explains that Randall made this PSA because he has experienced this multiple times in the last month, and that the assassins should try harder next time.

Alternate interpretation of the waving gesture[edit]

Note that in this comic, as currently illustrated, there appears to be sufficient room in the median strip for the waiting car to pass the first set of lanes and stop in the median strip, protected from passing traffic on both sides, to legally wait for the second stream of traffic to safely subside. Waiting in this median turning area is a normal maneuver in suburban and exurban US areas where these types of non-signaled intersections are common. There's no reason to assume that the supposed would-be assassin is not simply waving the waiting car to the safety of the median strip. Randall's message of caution is still sound, but he accidentally

illustrated an intersection diagram that fails to optimally support his case.
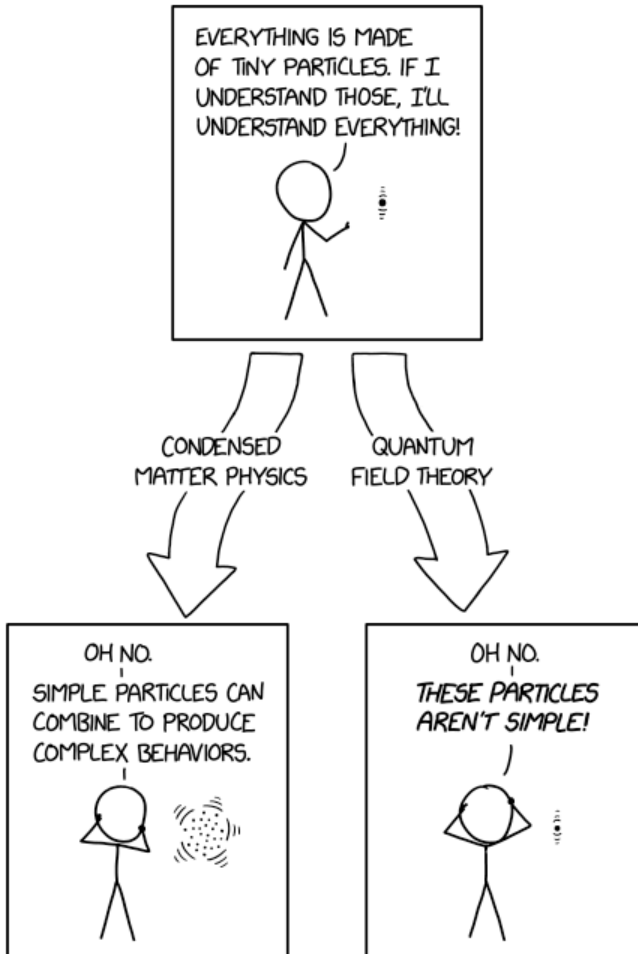
Legality

Median strips are typically used to allow vehicles to safely make left turns without impeding the flow of traffic. When emerging from a side road, vehicles can cross the first lane(s) of traffic and wait in the median strip until it is safe to merge into the opposite lane(s).

- In Texas, using the median strip to wait for a gap in traffic is generally acceptable. The Texas Department of Public Safety suggests that drivers use the median strip when appropriate. Source: Texas laws
- The state of Utah also allows this to happen.
- In Denmark, it is considered bad practice to pause in the median strip when crossing; left turns should be carried out in a continuous maneuver.

#2933: Elementary Physics Paths

May 15, 2024

Panel 1:
EVERYTHING IS MADE OF TINY PARTICLES. IF I UNDERSTAND THOSE, I'LL UNDERSTAND EVERYTHING!

CONDENSED MATTER PHYSICS

QUANTUM FIELD THEORY

Panel 2 (left):
OH NO.
SIMPLE PARTICLES CAN COMBINE TO PRODUCE COMPLEX BEHAVIORS.

Panel 3 (right):
OH NO.
THESE PARTICLES AREN'T SIMPLE!

==COSMOLOGY==> 'Uhhh ... how sure are we that everything is made of these?'

Explanation

This comic explores the complexities of understanding the fundamental building blocks of the universe.

The absurdity of understanding everything starting from just understanding basic particles is similar to the fallacy presented in 1570: Engineer Syllogism.

In the first panel, Cueball expresses the idea that if he understands the behavior of tiny particles, he'll understand everything. This reflects a common scientific pursuit, reductionism, to uncover the basic principles underlying all physical phenomena in order to understand them. For example, most chemical reactions can be explained as the recombinations of a few dozen common elements.

The comic then splits into two branches representing different fields of physics which refute Cueball's optimistic assumption: condensed matter physics and quantum field theory.

On the left, the concept of antireductionism (or holism) is demonstrated by the Condensed Matter Physics branch. Cueball encounters a cloud of vibrating particles, which symbolizes the complexity that arises when simple particles combine to produce complex behaviors. The issue with reducing down to particles is that the number of different interactions between particles to understand makes the topic no longer simple.

This highlights the challenge of predicting macroscopic properties from microscopic interactions, a central theme in condensed matter physics. This is shown in everyday life, from things like a baseball curving through the air, to how a mirror reflects light. 1734: Reductionism also touches on the impracticality of gaining knowledge about a larger construct through understanding its constituent parts.

On the right, in the Quantum Field Theory branch, Cueball is faced with the issue that particles at the quantum level aren't simple. Quantum Field Theory deals with the fundamental particles and forces of nature, and it describes a complex world where particles can behave as both waves and particles simultaneously, among other strange phenomena.

The title text introduces a third branch: the field of cosmology, which deals with the large-scale structure and history of the universe. Cosmology suggests that even our catalog of the most fundamental particles might be inadequate - perhaps an allusion to theorized phenomena like dark matter and dark energy - raising questions about the nature of existence itself.

No matter how you study the universe, it's complicated.[citation needed]

#2934: Bloom Filter

May 17, 2024
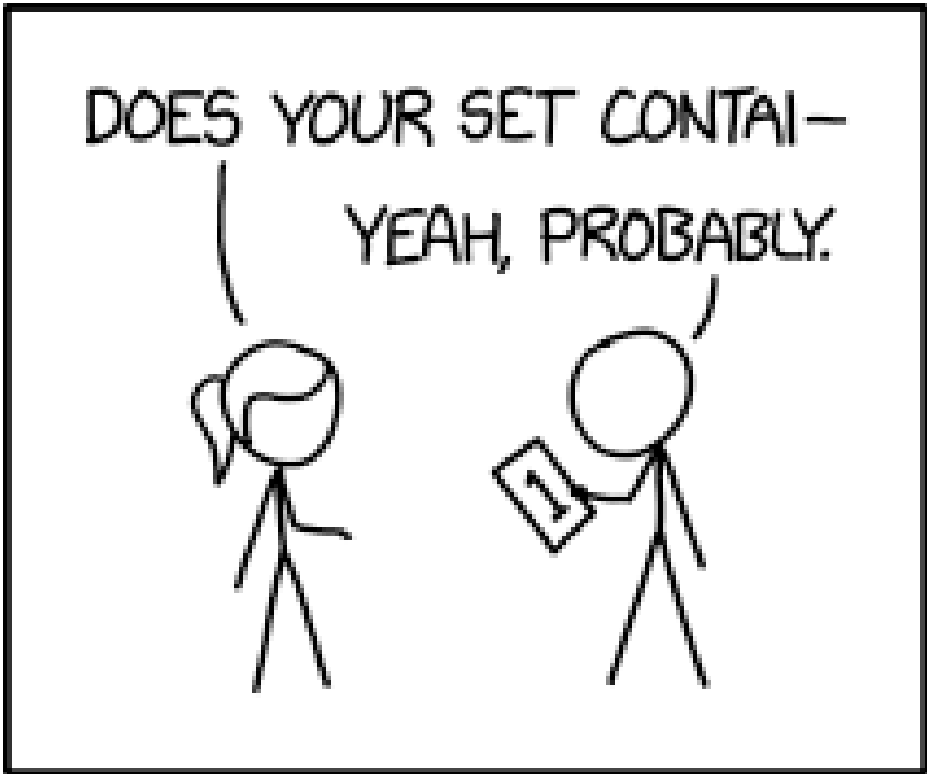
Sometimes, you can tell Bloom filters are the wrong tool for the job, but when they're the right one you can never be sure.

Explanation

The comic is about a data structure called a Bloom filter. Software engineers use Bloom filters to check if something is probably in a set or to estimate how many things are in that set, using limited memory.

- One example: the Chrome web browser used to store a Bloom filter of URLs that were known to be malicious, based on a database that was too large to store locally. Chrome used that Bloom filter to confirm that it didn't need to warn the user that they were visiting a malicious page. Only in the rare cases that the Bloom filter said the URL might be malicious, Chrome would send the URL to an external service to confirm whether it was known to be malicious. The developers didn't want the browser to send every URL to the external service because that would leak the user's entire browsing history to the service and would add an unnecessary network delay whenever a web page was loaded.

Here's how a Bloom filter works:

In the comic, Cueball is holding a piece of paper or tablet computer with a large "1" digit on it. This is labeled as a 1-bit Bloom filter, which is almost useless. When empty, it correctly returns a negative for any item tested, but as soon as one item is added the bit is set to 1, and now it unhelpfully says that any item tested might be in the set. Its size estimate also becomes "between 1 and infinity," which isn't helpful.

Having multiple hash functions is pointless for a 1-bit filter since they all end up pointing to the same single bit, which would return the exact same answer as a result.

The title text carries the characteristics of the Bloom filter into the decision-making process for choosing a Bloom filter over other candidate data structures. Analogously (according to the text), you can be sure when they are not the best approach but only conclude that they are with a limited degree of probability.

#2935: Ocean Loop

May 20, 2024
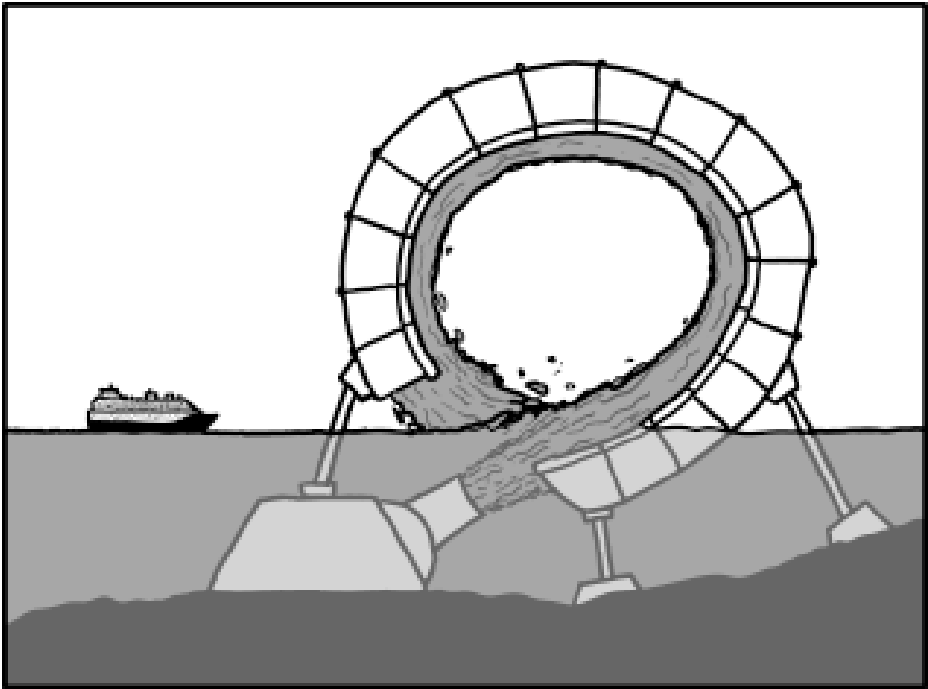
I DON'T KNOW WHY THE
CRUISE LINE FIRED ME.

I can't believe they wouldn't even let me hold a vote among the passengers about whether to try the loop.

Explanation

Upon hearing the term "ocean loop", many people think of horizontal ocean gyres or ocean currents. This comic illustrates a vertical, rather than horizontal, ocean loop.

The comic shows a large construction, rising out of the sea to dwarf a nearby cruise ship. It involves a submerged water-jet sending water up out of the surface and round a rollercoaster-loop-like water-flume trough. The scale is such that it seems that the ship, once caught in the necessarily powerful stream of water, is also intended to be propelled around the inverting loop before "safely" exiting at the other side.

The design is reminiscent of the infamous 'Cannonball Loop' water slide - a fully-functional water slide complete with a loop-de-loop - which was one of many famously dangerous rides and attractions at Action Park; a theme park in New Jersey that became iconic for its blithe disregard for human safety, and the numerous accidents and deaths at the park as a result. This video, among other potentially dangerous water slides, shows 2 such loop-de-loop water slides (1 and 2). Apart from various other issues regarding large "loop-de-loops", the stream of water required to maintain this setup would be acting upon the nearby water and so the nearby ship is probably already close enough to be drawn into the loop (with the best option left being to deliberately steer into it, rather than risk being swept uncontrollably into the structure), assuming that it isn't already caught in the tug of the

water-jet's inward flow.

Even assuming a "successful" loop (the stresses and rotation inflicted by the loop are likely beyond the design limits of such a vessel), the emergence back into the relatively calm and stationary waters beyond the exiting outflow would be a severe challenge to navigation. On the positive side, due to the nature of buoyancy, if the loop structure itself is capable of withstanding the force of the water being forced round it then it should be equally capable of withstanding the passage of the ship, unlike an impromptu rail-based loop which might stand up on its own but then shake itself apart when the first carriage is sent around it.

Not only would there be problems for the engineers, ship and navigators, the "ride" wouldn't be pleasant for the ship's passengers in any way. Many of the passengers would suffer extreme injuries from the changes of velocity (up to 370km/h or 230mph based on a loop radius of 3 x ship length) and rotation (unlike rollercoasters, or even airplanes during simple take-off and landing, passengers aren't normally strapped down). It is possible that the initial extreme undercurrent would capsize the ship. Depending upon where in the ship you were, the centripetal forces and the ship's rotation may not match for all passengers, forcing anyone not properly secured out towards the bow or stern. As well as the passengers, this also is relevant to all unsecured items (e.g. knives and forks would go flying off tables), as well as the dangers of breakable glass, liquids and many other dangerous objects which could create hazards even (or
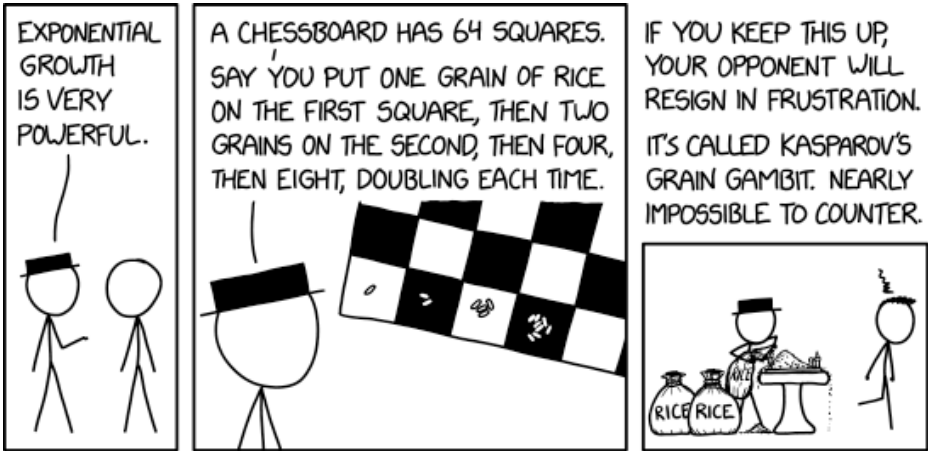
particularly) against those who have strapped themselves down to prevent their own movement through the ship.

Because of all these safety concerns, the caption, "I don't know why the cruise line fired me", suggests that someone in the company realized this would not be a good idea, and shut down the concept. However, the title text, "I can't believe they wouldn't even let me hold a vote among the passengers about whether to try the loop", implies that the narrator (whether because they simply hadn't thought it through properly, or they are someone with a sadistic nature) actually managed to get as far as building this loop and having a ship ready to try it. Considering the vast budget that would have been required to realise this concept, it appears that oversight at the cruise company is not what it could be, and perhaps others should be in line for firing as well (if it has not already bankrupted the company).

When those in charge of the ship objected to sailing into this loop, the builder attempted to get around this by having the passengers vote on it. Presumably worried that opening the decision-making process to the passengers might favor the exciting risk over the well-founded reason of the staff, those in charge put a stop to that too. Cruise ships generally don't function as democracies, even outside of absurd situations such as the one depicted.

#2936: Exponential Growth

May 22, 2024

EXPONENTIAL GROWTH IS VERY POWERFUL.

A CHESSBOARD HAS 64 SQUARES. SAY YOU PUT ONE GRAIN OF RICE ON THE FIRST SQUARE, THEN TWO GRAINS ON THE SECOND, THEN FOUR, THEN EIGHT, DOUBLING EACH TIME.

IF YOU KEEP THIS UP, YOUR OPPONENT WILL RESIGN IN FRUSTRATION.

IT'S CALLED KASPAROV'S GRAIN GAMBIT. NEARLY IMPOSSIBLE TO COUNTER.

RICE RICE

Karpov's construction of a series of increasingly large rice cookers led to a protracted deadlock, but exponential growth won in the end.

Explanation

In this strip Black Hat begins by demonstrating exponential growth, using a variation of the wheat and chessboard problem, a classic demonstration of this mathematical principle. Exponential growth involves an initial quantity being multiplied by any number greater than one again and again. It can cause small numbers to compound into very large numbers faster than might be intuitive. This principle is important in a number of real life applications, ranging from biological growth to inflation to reaction kinetics.

The earliest versions of this story come from India and involve a man (the inventor of chess, in some tellings), being offered a reward by a king, and asking that a single grain of wheat (rice, in some versions) be placed on the first square of a chessboard, two on the second, and each subsequent square having twice as many grains as the one before. In the story, the king generally laughs off such a reward as being trivial, but soon learns that the reward would be impossible to pay. Since a chessboard contains 64 squares, the final square would contain 2^{63} (approximately 9.2 quintillion) grains. This would be around 600 billion tonnes of wheat (even in modern times, would be centuries of global wheat production).

In some versions of the story, the man is executed for embarrassing the king and/or being over-greedy; in others, he's rewarded for his cleverness; in yet others he becomes king himself as a consequence. There are also

other versions that subvert the well-known tale by the king not being so naïve as to fall for the 'trick' played by the creator of the problem.

Black Hat initially appears to be using this example, to demonstrate a mathematical principle, but actually turns out to be using it to "win" a chess match by covering the chess board in rice until his opponent quits out of frustration. Naturally, despite his claims that it's "nearly impossible to counter", under the International Chess Federation (FIDE)'s Laws of Chess, this would be illegal on several levels, as deliberately distracting or annoying your opponent is a violation, as is deliberately displacing the chess pieces. Black Hat being Black Hat, he likely simply doesn't care, and counts it as a win when his opponent stomps off out of annoyance.

Garry Kasparov and Anatoly Karpov are both Russian chess grandmasters and former world champions. The two men famously competed for the world championship in the 1980s. The Kasparov gambit is a famous gambit that Kasparov played multiple times (but not, as Black Hat's is, something that can be played very early in the game). The title text implies that Kasparov actually tried Black Hat's method on Karpov, who attempted to consume all the rice with "increasingly large rice cookers", but eventually couldn't keep up. While this is obviously fictional, it fits with the principle of exponential growth. If exponential growth is unrestricted, it will eventually grow beyond the constraints of anything that could plausibly be built to contain it.

In any case, it appears that in his enthusiasm to enact his scheme, Black Hat has neglected to even set up his own pieces (or they have already been completely buried), never mind wait for the game to commence, so his opponent has nothing to resign from - indeed his king still appears to be standing as he walks away.

#2937: Room Code

May 24, 2024

Panel 1:
OKAY, I NEED TO REMEMBER THAT THE ROOM CODE IS 020518.

Panel 2:
EASY—JUST MEMORIZE IT AS "THE FIRST THREE PRIME NUMBERS, IF YOU REALIZED YOU COULDN'T REMEMBER WHAT CAME AFTER 2 AND STARTED TO PANIC AND GET THEM INCREASINGLY WRONG."

Panel 4:
...ARE YOU MAD BECAUSE THAT ACTUALLY WORKS?

WHY IS MEMORY LIKE THIS?
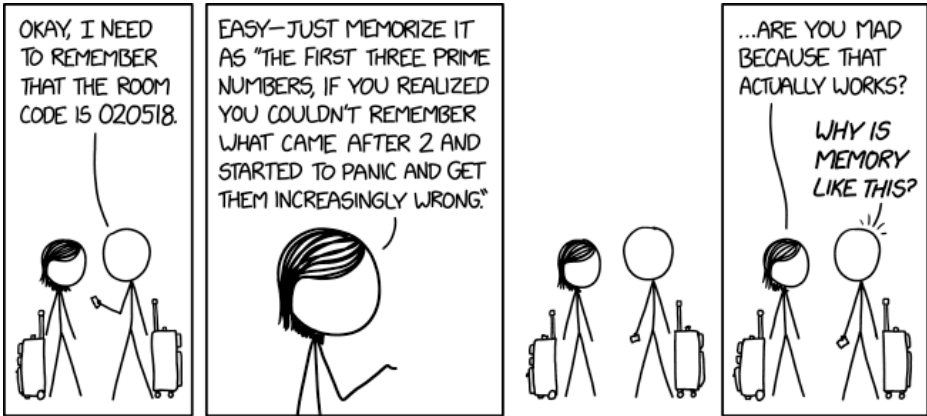
Sorry to make you memorize this random string of digits. If it helps, it can also double as a mnemonic for remembering your young relatives' birthdays, if they happened to have been born on February 5th, 2018.

Explanation

Cueball and Megan are on vacation or otherwise traveling, and receive a code for their hotel room. Megan gives a seemingly nonsensical and unhelpful mnemonic by which Cueball can remember it... which, inexplicably, actually helps Cueball to remember the code. Cueball becomes VERY angry on realizing this.

The first three prime numbers are actually 2, 3, and 5. So this technique easily identifies the first two digits "02". "05" is slightly wrong because it's not the second prime number; it's the third. And "18" is even more wrong because it's not actually a prime number; it's 2 × 32.

So the mnemonic itself doesn't really provide the method for remembering the code. Instead, figuring out how to apply the bogus mnemonic will reinforce your memory of the code. Unless you actually happen to be really bad at prime numbers and panicked while remembering them, in which case the bad mnemonic actually... helps?! Why is your memory like this?!

The title text points out that the code is also similar to a date in the (potentially ambiguous) MMDDYY format - not an unexpected choice, seeing as Randall lives in the United States - so if you happen to have a relative who was born on February 5th 2018, the memorized code will help you remember this date if using said date format. It is also a valid date in the DDMMYY format but in that case it would be the 2nd of May 2018, or in YYMMDD

format, in which case it refers to 18th of May 2002.

#2938: Local Group

May 27, 2024
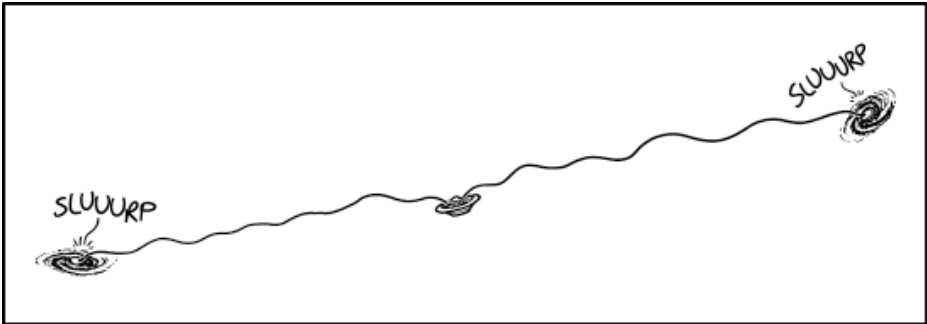
ASTRONOMERS HAVE DETERMINED THAT THE MILKY WAY AND ANDROMEDA ARE CURRENTLY SLURPING UP THE SAME STRAND OF COSMIC SPAGHETTI, SUGGESTING THAT IN 5 BILLION YEARS THEY WILL LIKELY KISS.

Cosmologists estimate the spaghetti strand to be about 200 septillion calories, though it could be higher depending on the nutritional value of dark matter.

Explanation

In less than 5 billion years into the future, the Andromeda Galaxy is expected to collide with the Milky Way. This comic suggests this will happen when both galaxies get into a kissing distance after having slurped the same cosmic spaghetti strand. This is a spoof of a famous scene in the movie Lady and the Tramp, where the titular dogs are eating spaghetti at an Italian restaurant. They happen to be eating the same strand from opposite ends, so they end up meeting in the middle and kissing. This scene was mentioned before in 2612: Lightsabers, and has been referenced extensively in other media.

It's possible that this is also a reference to Pastafarianism, the spoof religion which claims that the universe was created by a "flying spaghetti monster". If both galaxies are eating one of the deity's "noodly appendages," they may be doing what the monster wishes, since one of the religion's holidays is about eating lots of pasta.

The title text figure of 200 septillion (2×10^{26}) calories for the Milky Way-Andromeda noodle equates to approximately 2500 calories per foot of noodle. This value makes sense only if Randall is referring to the physics/chemistry "small" calorie (= 4.184 joules) rather than the dietary "large" Calorie (= 4184 joules). Dietary Calories, also called kilocalories (kcal), would be the usual meaning in a food-related context like this one, but Randall was trained as a physicist and apparently used

the small calorie here. Having 2.5 dietary Calories per foot is roughly correct for a noodle size between thin spaghetti and angel hair. A noodle with similar ingredients and 2,500 dietary calories per foot would be roughly 26 centimeters in diameter, and might more properly be considered a type of pastry (much to Beret Guy's delight).

The nutritional value of dark matter refers to the fact that evidence of 'dark matter' is particularly found in cosmic filaments and the cosmic web, implying that such "cosmic spaghetti" would have an appreciable amount of dark matter "sauce" on it. But, because the exact nature of dark matter is unknown, it is likely even more difficult to identify the calorific content that it might provide. Note that these filaments are much larger structures than the Local Group of galaxies that includes the Milky Way and Andromeda.

RESULTS OF ALGORITHM COMPLEXITY ANALYSIS:

AVERAGE CASE	O(N LOG N)
BEST CASE	ALGORITHM TURNS OUT TO BE UNNECESSARY AND IS HALTED, THEN CONGRESS ENACTS SURPRISE DAYLIGHT SAVING TIME AND WE GAIN AN HOUR
WORST CASE	TOWN IN WHICH HARDWARE IS LOCATED ENTERS A GROUNDHOG DAY SCENARIO, ALGORITHM NEVER TERMINATES
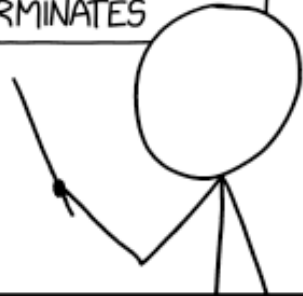
PERPETUALLY OPTIMISTIC CASE: Early in the execution, our research group makes a breakthrough on proving P=NP.

Explanation

Cueball is teaching about an algorithm's complexity. The average-case complexity of the algorithm is written in Big O notation as O(n log n), expressing the asymptotic runtime of the algorithm as the number of inputs to it grows larger and larger.

The comic's joke involves taking the terms "best case" and "worst case" far more broadly and literally than intended. Cueball presents not just the best/worst cases for the data input into the function, but also the global environment as a whole, taking in factors such as the United States Congress which should fall far outside the algorithm's scope.

In particular, the joke regards the analysis of a closed system, which is common in engineering. An algorithm's "best case" is typically its runtime when its inputs have optimal values and it runs in as little time as possible. One example would be a sorting algorithm that is called with an already-sorted list of numbers; an algorithm may only need to check each item in the list, in one pass, to confirm this, compared with having to compare an arbitrary number of items against an arbitrary number of others across a number of cycles. The worst case would be when a list is 'unsorted' in a way that presents the maximum number of challenges and actions to the sorting algorithm (possibly, but not necessarily, when presented with the initial list exactly in the wrong order/reversed). These two limits can each be given by an

O-notation, but a single O-notation generally indicates the mean complexity of operation encountered for all inputs.

The joke here is that not only does this algorithm 'run' quicker than what would otherwise be considered its best case scenario, by being terminated early because it is deemed to be 'unnecessary', but its runtime appears to be an hour shorter still because of an act of Congress changing daylight saving time, giving it an end time (in local time) that is an hour less than it would have been under other circumstances. Potentially this would result in an end time that is recorded as earlier than its start time (depending on how the times are handled), and therefore an apparently negative 'runtime'. Daylight saving time is a recurrent theme on xkcd, and it is clear that Randall is not a fan, so Congress making surprise DST changes is another way for Randall to mock the concept.

The "worst case" refers to the movie Groundhog Day, in which the same events occur over and over in a sort of time loop. (This movie has been referenced before in 1076: Groundhog Day.) If the hardware running the algorithm is present in this kind of loop then it may also reset to a previous time before it gets finished, meaning the algorithm would never terminate. This gives rise to a philosophical question about the movie as to whether the whole world is reset after every day, or just the town where the movie takes place. If it is just the town, and you could still connect to their hardware from outside, then from that perspective the algorithm would appear

to be taking an interminably long time to run. If the whole world resets, since people (aside from the movie's main character) do not experience the reset, it would only appear to take as long as it does once the last (non-resetting cycle) leads it into the expected following day.

This may be an indirect reference to the halting problem, a famous problem in computer science. The halting problem is undecidable, meaning that no general algorithm can tell whether a given algorithm will halt, but the widely accepted traditional proof of this relies on external action on details of a system considered closed.

The title text refers to perhaps an even more famous problem in computer science: P versus NP. This asks whether every problem whose solution can be quickly verified (in nondeterministic polynomial time, NP) can also be quickly solved (in polynomial time, P). The P-versus-NP problem is one of the seven Millennium Prize Problems, and as such has a $1 million prize for its solution. Presumably, the problem discussed here is in NP, so if P=NP, its worst-case runtime would be some polynomial O(nk). However, P vs. NP is a Millennium Prize Problem for a reason; most computer scientists expect that P≠NP, so hoping for a breakthrough in proving P=NP is "perpetually optimistic". This may be a reference to optimism bias and the planning fallacy, whereby people tend to assume that the most favourable outcome will be the most likely.

#2940: Modes of Transportation

May 31, 2024

ZONE OF PRACTICALITY

ZONE OF SPECIALTY AND RECREATIONAL VEHICLES

TRAINS
AIRLINERS
CARS SCOOTERS
BICYCLES
BOATS
WALKING
LIGHT AIRCRAFT
GO KARTS
SKATEBOARDS
ROLLERBLADES
SKIS
UNICYCLES
SLEDS
BUMPER CARS

MOTORCYCLES
HELICOPTERS

?????

HOT AIR BALLOONS

CONVENIENT FOR TRAVEL

DANGEROUS →
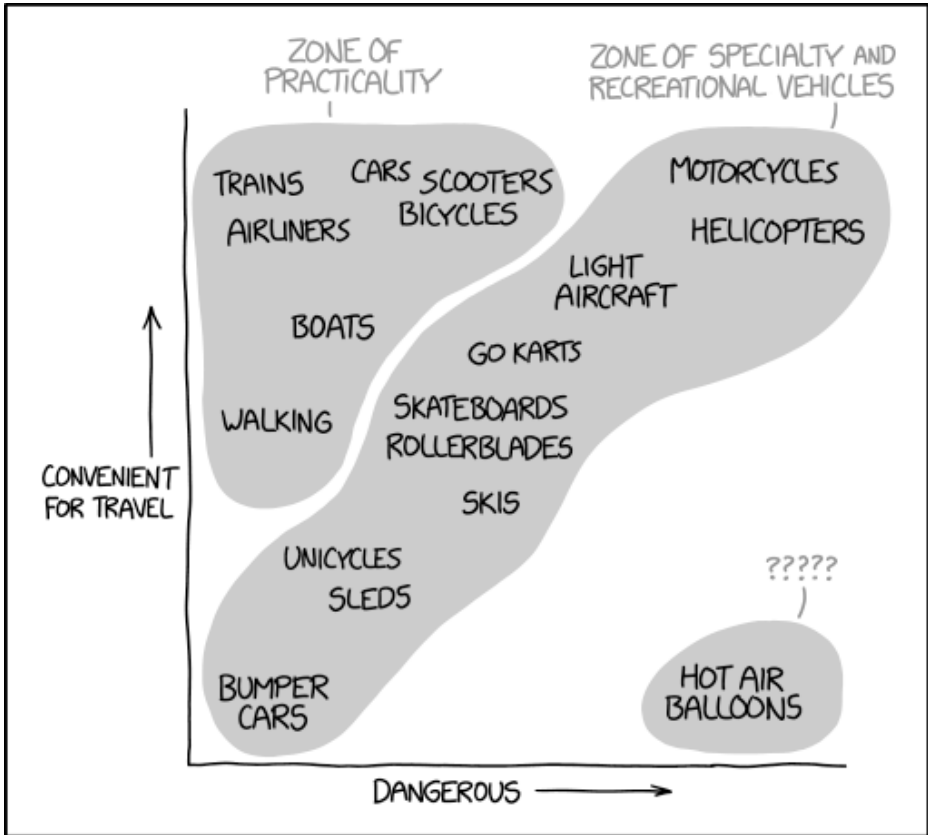
HOT AIR BALLOONS ARE THE OPTIMAL MODE OF TRANSPORTATION, IF YOUR OPTIMIZATION ALGORITHM HAS A SIGN ERROR.

My bold criticism might anger the hot air balloon people, which would be a real concern if any of them lived along a very narrow line directly upwind of me.

Explanation

Randall's chart compares different modes of transportation by how convenient and dangerous they are. At the top-left (high in convenience and low in danger) are airliners and trains, as these are both fast-moving vehicles on which many millions of dollars have been spent to make them safer. In the top-right, motorcycles are at the same convenience level, but are rated much more dangerous, since they are easy to lose control of at high speeds, and careless drivers (of cars) can easily hit a motorcycle and cause extreme harm. Things like unicycles (bottom-left) are considered much lower on the convenience scale, being not very fast or easy ways to travel, but relatively safe, while towards the centre, skis are apparently moderately convenient and moderately dangerous, since they are relatively easy to fall on if going fast downhill. Way out on their own in the bottom-right, hot air balloons appear to be unique in being rated least on convenience and highest on danger. Presumably, modes of transportation similar to hot air balloons (like zeppelins and blimps) are left off the chart to increase the gap for comedic effect.

The modes are grouped into several zones by darkened backgrounds -- the easiest or most effective that are also the safest ones (trains, cars, walking, biking, boats, etc.) are in the Zone of Practicality at the upper left. The ones that are mixed, ranging from very useful for travel but dangerous (motorcycles and helicopters) in the upper-right, through moderately dangerous and

moderately unpractical (go karts, skateboards, rollerblades, skis, light aircraft) in the middle, to quite safe but totally unpractical for travel (bumper cars, unicycles, sleds) in the lower-left are in the Zone of Specialty or Recreational Vehicles. At the extreme of dangerous and very unpractical (lower-right) is a zone labeled simply ????? containing only one mode: Hot Air Balloons.

Because a hot air balloon is rated so poorly, if an optimization algorithm considers it the optimal mode of transportation, it must be the result of a sign error (e.g. having a minus sign where a plus sign is supposed to be, or vice versa), making the algorithm optimize for the opposite result by mistake. This could be because, unusually, on the y axis of the chart higher is better, whereas on the x axis lower is better. If these were treated the wrong way around, it would result in the air balloon appearing to be the best result. More typically, you might plot convenience vs safety, so that a higher value on either axis would represent a better result. However, both measures are still likely to need to take underlying data (for safety, incident counts, etc.; for convenience, travel time, etc.) and invert them, leading to potential for errors.

In order to compare the relative danger from each mode of transport, one can look at statistics of fatalities and injuries sustained during each activity. Traditionally this can be reported in fatalities/KSI per mile driven or passenger mile (or other unit of distance), to account for the fact that some modes are used much more than

others and make valid comparisons. They may also be reported per capita (but this ignores the relative usage of different modes), or per journey (but this doesn't take into account the fact that different modes typically have different journey lengths and times). All of these are somewhat flawed, since they are really measuring the danger to users of that mode of transport, both from their own conveyance, and from other sources such as other road users. Since ballooning is not a very common mode of transport, hot air balloon incidents are correspondingly uncommon, and flights are not routinely monitored or registered, it is difficult to draw strong conclusions from the data for hot air balloons.

The title text makes a joke that if a hot air balloon enthusiast disagrees with the ranking and is angered by it, they may wish to remonstrate or retaliate, but will have a difficult time getting to Randall's house with their preferred mode of transportation, because they are limited to travelling in the direction of the wind. If they chose an alternative form of transport, they would be making his point for him. In reality, hot air balloons have some freedom to choose their direction of travel, since by controlling their altitude they can access different wind directions at different heights. Randall should, therefore, be concerned about hot air balloonists who live within a wedge spanned by the various wind directions accessible on a given day. In principle, if the weather conditions are favorable, this could cover every direction from Randall's house. The phrase "hot air balloon people" is reminiscent of "autogyro people" from the title text of 1972:

Autogyros.

Curiously, the comic includes most common forms of transport, and a number of less common ones, but omits examples such as buses (a mass transit solution arguably more convenient than trains). It is not clear if this is an error, or a deliberate choice to maintain the comic's layout and presentation. Another omitted mode of transportation is horseback riding, which would possibly win over hot air balloons in sign-error optimization because in spite of horseback riding's increased convenience relative to hot air balloons, it is also more dangerous, especially if counting horse deaths. However, unlike hot air balloons, horseback riders could get to Randall's house even if the wind is not blowing in the exact right direction, and once they are at Randall's house, they could potentially have their horse kick down Randall's front door or even kick Randall, the latter of which could be fatal, so perhaps Randall intentionally omitted horses from the diagram for his personal safety.

This is the second comic in a row to feature an algorithm.

#2941: Cell Organelles

June 03, 2024

CELL ORGANELLES

SMOOTH ENDOPLASMIC RETICULUM
LITHOSPHERE
O-RING
PITH
NUCLEUS
NUCLEOLUS
NUCLEOLOULOUS
NUCLEONS
DRAIN PLUG
EVIL ENDOPLASMIC RETICULUM
HYPOALLERGENIC FILLING
WEAK SPOT
MITOCHONDRIA
MIDICHLORIANS
SEEDS
VENTRICLE
MANTLE
SLIME
VITREOUS HUMOUR
ROUGH ENDOPLASMIC RETICULUM
CELLOPHANE
NATURAL FLAVOR
PLEIADES
STICKY ENDOPLASMIC RETICULUM
NORTON ANTIVIRUS
GOLGI APPARATUS
GOLGI
CARBONATION
HUMAN SKIN
CHLOROPLASTS IF YOU'RE LUCKY

It's believed that Golgi was originally an independent organism who was eventually absorbed into our cells, where he began work on his Apparatus.

Explanation

This comic shows a biological cell diagram with a mix of real and fictional organelles, giving both accurate cell biology terms and humorous ones. Actual cell components include the nucleus, mitochondria, and Golgi apparatus, while unrelated concepts come from geology, engineering, antivirus software, and even Star Wars. Labels like "evil endoplasmic reticulum" and "sticky endoplasmic reticulum" are variations of real cellular organelles. Other labels like "pith," "mantle," and "Vitreous humor," are borrowed from other types of circular cross-sectional diagrams (e.g., of fruit, planets, and eyeballs).

The title text is a fictional backstory to the Golgi apparatus, an essential cell organelle involved in processing and packaging proteins. It suggests that Camillo Golgi, the scientist who discovered the Golgi apparatus, was originally an independent organism that was supposedly absorbed into our cells, where it then started working on what is now known as the Golgi apparatus. The joke is a satirical take on endosymbiotic theory, which posits that certain organelles within eukaryotic cells, like mitochondria and chloroplasts, originated from independent symbiotic prokaryotic organisms that were absorbed by a host germ cell. Golgi is drawn in the comic as a cute little alien.

#2942: Fluid Speech

June 05, 2024

FUN FACT: EXPERIENCED SPEAKERS CONSTANTLY MERGE, DROP, AND ALTER SOUNDS WHEN TALKING AT NORMAL CONVERSATIONAL SPEED TO OPTIMIZE FOR EFFICIENT MOUTH MOVEMENT.

MORE FLUID ⟶

GOING TO
/goʊɪŋ tu/

GOIN' TO
/goʊɪn tə/

GONNA
/gʌn.ə/

HOW FLUENT SPEAKERS *ACTUALLY* SAY IT WHEN SPEAKING RAPIDLY
/gə̃/
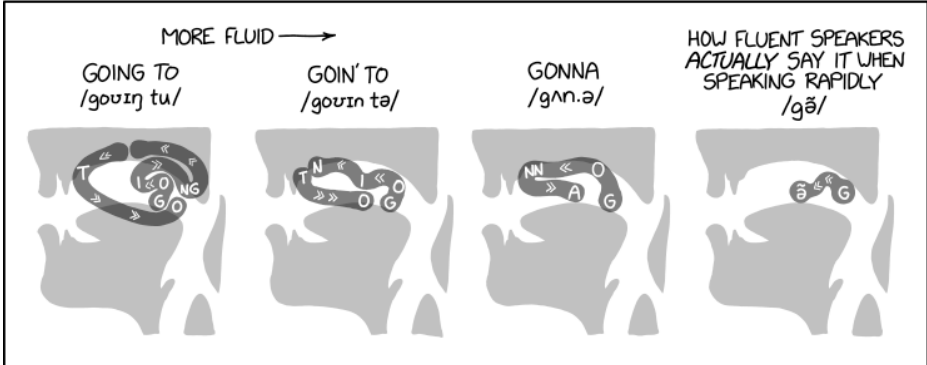
IF YOU THINK *YOU* DON'T DO THIS, TRY TO USE "HOT POTATO" IN A SENTENCE AND FULLY PRONOUNCE THE FIRST "T" WITHOUT SOUNDING LIKE AN ALIEN IMPERSONATING A HUMAN.

Thank you to linguist Gretchen McCulloch for teaching me about phonetic assimilation, and for teaching me that if you stand around in public reading texts from a linguist and murmuring example phrases to yourself, people will eventually ask if you're okay.

Explanation

This comic is about sandhi.

Randall states that people often unconsciously shorten words in various ways when speaking to optimize the fluidity of speech.

He then presents four side-view diagrams of the human mouth and paths depicting how it might conceptually move (it depending a lot on how the individual normally forms even the major phonemes) when saying increasingly fluid versions of "going to."

The first diagram gives the pronunciation /ɡoʊɪŋ tu/ GO-ing TO. This is the version found in dictionaries and used when one is speaking slowly and deliberately. Here, the tongue and lips have to move a lot. The phrase starts at the back of the throat with a velar /g/ and moves into the diphthong OH /oʊ/ and the approximant /w/ to the KIT vowel /ɪ/. (Though it's not in the traditional IPA transcription or the comic, most native accents will insert a [w] between [ʊ] and another vowel.) The tongue then has to move right back to where it started for the "ng" in "going", the velar /ŋ/, followed by an even bigger jump forwards to the alveolar /t/ and back again for the back vowel /u/. Since /t/ is a voiceless consonant, the vocal cords will briefly stop vibrating, interrupting the sound, which the diagram illustrates as a gap in the path.

The second diagram shows a slightly more efficient pronunciation, in which the /ŋ/ is replaced by an /n/

instead since both /n/ and /t/ are alveolar sounds. The final /u/ weakens to the more neutrally positioned /ə/, which is the "default" vowel (aka you should be making this sound if you relax your mouth completely and give a small grunt). (For more about Schwa, see 2907: Schwa.) All doubling back of the tongue is now removed, leaving only a small, nearly closed loop.

The third diagram shows an even more efficient and very common pronunciation of the phrase, /gʌnə/ GUN-na. Here rather than optimizing tongue movement hard-to-pronounce sounds are removed or further replaced instead. The /t/ is dropped leaving only /n/, while the vowel(s) of the first syllable go from /o/ to /ʌ/ between which the only difference is the optional rounding, or pursing, of the lips - though more likely given Randall Munroe's prior comics demonstrating a STRUT-COMMA merger, a supposed /ə/.

The fourth diagram shows the most reduced pronunciation. The /n/ is lost as a consonant in its own right, with only remnants of its existence found by the nasalisation of the preceding vowel where part of the airflow is redirected through the nose. (This is, incidentally, the same way that French got its famous nasal sounds - sequences of what used to be vowel + /n/ from Latin were reduced.) This way, the only motions one must make is to articulate the /g/, which some would voice by a movement of the rear tongue although parts of the larynx may primarily be employed by others. This pronunciation seems almost unconnected to the original phrase of "going to". However, English speakers

will still almost always understand this in context, and likely think they heard "gonna"

In some ways, this may also help explain how Neil Armstrong's line "One small step for a man" was heard over the radio as "One small step for man". As you move towards More Fluid, the phrase "for a man" can quickly become "foreh-man" and then "fur-man". While extensive research has been done elsewhere on this topic, when given the choice between a technical problem with the radio, and issues with phonetic pronunciation under pressure, the latter seems more likely.

In the bottom text, Randall comments on the perception of reduced pronunciations, remarking that while many perceive them as being sloppy, in reality deliberately pronouncing each word with the "supposed" pronunciation in its dictionary form sounds stilted, forced, and unnatural. The final T in the word "hot" is an example of this. Most people when thinking of T think there is only one way to pronounce it - usually the aspirated unvoiced alveolar plosive "tuh" found at the start of syllables - but in reality it varies widely depending on position and accent, most noticeable if one pronounces a word such as "teat". In this context the "t" in "hot" is replaced by a glottal stop; funnily enough, and perhaps ironically, despite being the same sound it is never stigmatized, unlike intervocalic "t"s such as bottle which some speakers, particularly some British ones, also replace with glottal stops (rendered 'humorously' as bo'oh). It you speak English in the British "standard" Received Pronunciation form you may have to put on a

fake American accent to understand this joke. It works best if you attempt an outrageous stereotype of a slurred non-English speaker.

The title text is a serious shout-out to linguist Gretchen McCulloch who has been teaching Randall about this stuff, but includes a joke about what happens when he tries these things out in public.

#2943: Unsolved Chemistry Problems

June 07, 2024

OUR LAB WILL BE WORKING ON CHEMISTRY'S TOP UNSOLVED PROBLEMS: ARBITRARY ENZYME DESIGN, PROTEIN FOLDING, DEPOLYMERIZATION, AND, OF COURSE, THE BIGGEST ONE OF ALL:

FIGURING OUT WHAT THE "p" IN "pH" STANDS FOR.

GRAND OPENING

I'm an **H** denier, in that I refuse to consider loose protons to be real hydrogen, so I personally believe it stands for 'pretend'.

Explanation

Every field of research has unsolved problems considered "important" or "significant" that motivate continued research. The scientists at what is apparently the "grand opening" of their new chemistry lab list several real chemistry problems, followed by one also-unsolved-but-less-scientific problem (the p in pH)

Arbitrary Enzyme Design:

Enzymes are catalytic proteins. Enzyme catalysis is often unique in comparison with other catalysis methods as it is highly specific, or tailored to a specific reaction. As such, enzyme catalysis, besides being the basis of all biochemical processes, is becoming increasingly relevant to industrial synthesis processes. As enzymes can easily be produced synthetically through recombinant gene technology, being able to design an arbitrary enzyme for any reaction would mean that effectively any reaction could be relatively easily catalyzed, revolutionizing the chemical synthesis industry.

Protein Folding:

Proteins are large molecules that consist of chains of amino acids. These amino acid chains become folded in extremely complex ways to form intricate 3D structures, and the way a protein is folded is of critical importance to its function. Because of the huge importance of proteins to biological life, biologists have devoted

significant attention over many decades to the problem of protein structure prediction. This refers to the ability to predict the 3D structure of a protein based on the amino acid sequence, and remains one of the most important problems in computational biology. The ability to predict protein structure purely from amino acid sequence — the so-called "de novo" prediction — is known in computational biology as an unusually difficult problem due to the complexity of amino acid chains. Known as "Levinthal's paradox," the number of possible conformations from the backbone conformations alone is estimated to be in the ballpark of 10^300. Despite this, protein folding occurs extremely quickly in reality. Because of this difficulty in sampling conformations, even with optimization, such as secondary structure prediction and Monte Carlo simulation, a "true" accurate simulation is extremely computationally expensive. Because of this, the most accurate solutions, such as AlphaFold, utilize a combination of homology modeling (sampling experimentally determined proteins with similar sequences to infer structural motifs and similarities) and deep learning to accurately guess protein structure. See also 1430: Proteins.

Depolymerization:

Polymers are very large molecules formed out of repeating subunits called monomers. Monomers are molecules, typically organic in nature, that can bond with at least one other molecule, with two or more making long chains or networks called polymers. That

process is known as polymerization. Depolymerization is breaking polymers down into the small molecules they were originally made from. This is done through a variety of processes, such as radiation, electrolysis, adding chemicals, and other means. Plastics are the best-known polymers, but cellulose, proteins, and DNA are also technically polymers. The huge number of varieties and mixtures in plastics makes recycling them a huge challenge, and there is increasing concern about plastic waste damaging the environment.

Polymerization is usually exothermic, releasing energy as heat. To reverse this would require adding energy in a targeted way. Simply destroying a polymer — by means of highly-reactive chemicals, heat, or radiation — doesn't generally release the monomer molecules to a significant degree; most of the reaction products are highly degraded. Most polymers are made by a process of catalysis, with the small monomer molecules interacting via a catalyst structure, often in liquid form, and the eventual product is usually solid. To reverse this would require getting the catalyst to interact in a very precise way with the solid polymer, and it's relatively difficult for the catalyst structure to get into the proper configuration with the solid tangled polymer molecules.

Another highly-desired depolymerization process would be to convert cellulose into its component glucose molecules. That glucose could then be used for a variety of different purposes, including fermentation to alcohol to use as a fuel. Currently, when plants are grown, much of the solar energy and carbon dioxide they absorb ends

up in the form of cellulose rather than as starch, sugar, protein, or other substances that we find useful. Our being able to make use of the cellulose would make farming much more energy-efficient. Some organisms are able to depolymerize cellulose by means of enzymes, but our ability to use similar processes on an industrial scale is still limited. (Those organisms use a complex multi-step biochemical process which essentially "invests" energy into splitting off a glucose molecule, then recoups the investment by metabolizing the glucose.) It's also possible to depolymerize cellulose at high temperature and pressure using nothing more than water and acid, but that process is energy-intensive. It might be possible to do it with a solar-heated reactor.

What the "p" in pH stands for:

"p" shows up in pH, pOH, pKa, pKb, and other things related to the concentration of H+ ions and OH- ions. The meaning of the "p" in "pH" has been the subject of much dispute. It is sometimes referred to as "power of Hydrogen", perhaps related to the fact that pH is a logarithmic scale, and the logarithm is the inverse of the exponented function and, in all three languages that pH was first published in, the word for "potency" is used for exponents. The term pH was introduced by Søren Peter Lauritz Sørensen, who did not publish his results in English, and more accurately translates as "hydric exponent". The letter p could stand for, in the languages in which Sørensen published: the French 'puissance', German Potenz, or Danish potens, all referring to the concept of the "exponent" in exponential functions.

Title Text: Hydrogen Denier

In the title text, Randall claims to be an H+ denier by refusing to consider loose protons to be hydrogen atoms, and as such, the "p" stands for pretend. Part of the joke is Randall's implication that this is a well-known conspiracy theory that he personally buys into (it isn't).[citation needed] The word "denier" is often used as shorthand for other conspiracy theories, such as a "climate change denier" or a "moon landing denier."

Here's a breakdown of this joke:

- H+ is the chemical symbol for a positively-charged atom of hydrogen, the smallest atom on the Periodic Table. Since hydrogen is normally just one proton and one electron, when you take the electron away, you make it positively charged (the + sign in the superscript) and you effectively end up with just a single loose proton. So the shorthand for "loose proton" is to refer to it as an H+ ion.
- pH is taught in high school science class to essentially measure the concentration of extra loose protons in, say, an aquarium. (Different fish prefer slightly different pH levels/alkalinity.) As mentioned earlier, you can interpret the term "pH" to be referring to the "p" of "H" -- the power/potency of H+ ions.

(Note that in reality, lone H+ ions do not exist in water, and instead they glom onto H_2O molecules to form H_3O+ and $H_5O_2+/(H_2O--H--OH_2)+$ due to intermolecular hydrogen bonding. If you don't know

what these chemical symbols mean, don't worry about it.)

But as an H+ denier, Randall doesn't consider loose protons to be hydrogen atoms. He has a purist's view of hydrogen, that it is just "pretending" to be hydrogen as soon as it loses an electron. As a denier, he interprets the term "pH" as referring to the concentration of "pretend Hydrogen".

#2944: Magnet Fishing

June 10, 2024
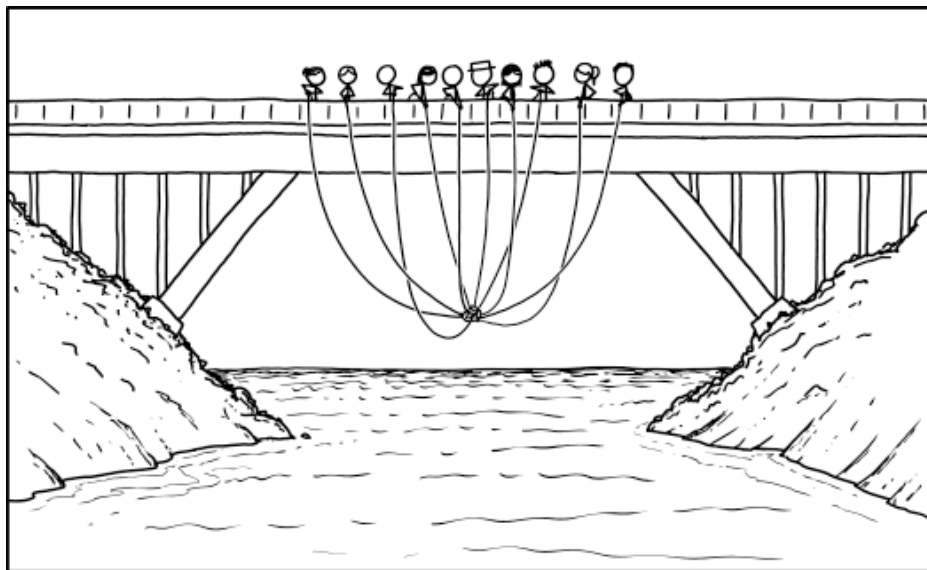
THE FIRST, AND LAST, WORLD MAGNET FISHING CHAMPIONSHIP

The ten-way tie was judged a ten-way tie, so no one won the grand prize, a rare fishing monopole.

Explanation

Magnet fishing is the act of using a magnet to find ferrometallic objects in a body of water. It can be used to recover specific lost items, help to clear a stretch of water of dumped items and/or simply to see what interesting (perhaps valuable, occasionally dangerous) items can be found. This is reminiscent of magnetic fishing games (such as "Let's Go Fishing" and "Go Fishing") where players use fishing rods with small magnets on the ends to "catch" fish.

The comic imagines a World Magnet Fishing Championship, apparently only held once, because of the contestants' magnets getting stuck together. This resulted in the fishing lines becoming tangled together, or "tied", for a pun on the competition being declared "tied". It also looks like a tautology, though the first "ten-way tie" depicts how the ten lines are 'knotted' together, and the second indicates the equality of the final score. This suggests that nobody 'fished' anything other than "all the other nine magnets", prior to the inevitable conclusion.

It's unclear why the World Magnet Fishing Championship has contestants competing simultaneously. Participants go one at a time in a great variety of sporting competitions where the arena or venue only suits one competitor at a time -- such as diving, figure skating, gymnastics, equestrian -- and the individual performances are graded and compared to

determine a winner. If the World Magnet Fishing Championship contestants took turns fishing from the bridge, it wouldn't have to be cancelled.

The title text states that the competition's prize would have been a "fishing monopole" which could refer to a fishing rod, also called a fishing pole, with only a single rod rather than multiple. Most fishing rods only have a single pole so this would not be considered rare. It could also refer to a magnet fishing rod where the magnet is a magnetic monopole rather than a magnetic dipole like all known magnets. This would certainly be rare since no magnetic monopoles have been found and thus would be a certainly be a valuable prize for a competition. The irony of this is that such a magnet would have alleviated the issue of the magnets attracting while fishing. The currently known laws of physics require that if magnetic monopoles exist, electric charge must be quantized. Electric charge is quantized which is consistent with (but does not prove) magnetic monopoles existing. Finally, 'pole position' (usually in Motorsport) is awarded to the first place qualifier in a competition. With all competitors coming joint first, this is a 'monopole' result.

#2945: Broken Model

June 12, 2024

HMM, LOOKS LIKE I ACCIDENTALLY SWAPPED THE PREDATION TERMS.

IF THIS WERE AN ECOLOGY CLASS, I WOULD HAVE TO FIX THAT.

UNFORTUNATELY FOR THOSE 20 POOR FOXES, THIS IS CALCULUS, AND THE MATH SAYS THESE 400 RABBITS ARE HUNGRY FOR MEAT.

$$N_{RABBITS}(0) = 400$$
$$N_{FOXES}(0) = 20$$
$$\frac{dR}{dt} = \cdots = \frac{dN}{dt} = \cdots$$
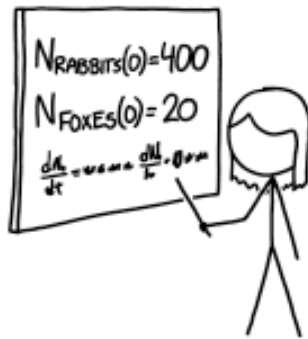
EVERY BROKEN MATHEMATICAL MODEL IS JUST A GLIMPSE INTO A TERRIFYING ALTERNATE UNIVERSE.

In addition to eating foxes, rabbits can eat grass. The grass also eats foxes. Our equations chart the contours of Fox Hell.

Explanation

This comic shows Miss Lenhart explaining a mathematical model of a predator-prey relationship. The model has the terms swapped, showing that 400 rabbits are preying on 20 foxes. The teacher realizes this mistake and says "If this were an ecology class, I would have to fix that." Instead of fixing the model, though, she instead begins to calculate using this flawed model, and notes that this model implies that rabbits are carnivores.

The equations start with Nrabbits(0)=400 and Nfoxes(0)=20, the number of rabbits and foxes at time 0, followed by what looks like the Lotka–Volterra equations, a pair of first-order nonlinear differential equations, frequently used to describe the dynamics of biological systems in which two species interact. One of the pair of equations describes the number of prey over time, the other the number of predators over time, differing only by a negative sign (and coefficients). It is easy to mix up which equation describes which species, leading to the inverted predator-prey relation described.

If this was indeed the case the rabbits would likely soon render the foxes extinct. They might not, if each rabbit requires to eat a very small amount of fox, and they hunt in packs, so that a single fox feeds many rabbits, but it would need to be a very small amount, very infrequently. The reason this doesn't happen in reality for rabbits is that they outnumber the foxes (20 foxes vs 400 rabbits) and thus enough of them can survive being preyed upon

to maintain the species. Often the predator takes the old and sick animals first, thus keeping the rest of the animals more healthy. But following the math of the wrong formula would soon lead to zero foxes. As per the title text, the rabbits could survive without the foxes to prey on, since they still eat grass (assuming that there is not some specific nutrition requirement that is only fulfilled by the foxes). However, this reality is terrifying for the foxes, because they are rendered as prey.

The title text extends the joke by looking at an even more flawed model that incorporates grass. In the real world, rabbits eat grass and foxes do not directly interact with grass. In this model, the fox-eating rabbits also continue to eat grass and foxes do interact with grass. Even more unfortunately for them, this is in the form of the grass eating foxes, creating a "Fox Hell".

As a matter of fact, grass pulls nutrients from air and soil and synthesizes its energy through photosynthesis, and may use foxes that have already died from other causes as fertilizer. Foxes do occasionally eat grass, although not as food, but for other health reasons.

#2946: 1.2 Kilofives

June 14, 2024

I DON'T SEE WHY ABRAHAM LINCOLN SHOULD BE THE ONLY ONE WHO GETS TO COME UP WITH WEIRD WAYS TO SAY NORMAL NUMBERS.

'Oh yeah? Give me 50 milliscore reasons why I should stop.'

Explanation

Abraham Lincoln's Gettysburg Address features the phrase "four score and seven" to refer to 87: a "score" is a group of 20, which literally translates as "four-twenties [and] seven". This is because English used to count by twenties (and some modern languages, including French still do, at least partially). However, this practice has died off and most English speakers nowadays would not use "score" in such a manner. Inspired by this, Cueball (possibly representing Randall) decides to use unusual prefixes to state the population of a town.

Metric prefixes can be added to a unit to scale up or down its magnitude. For example, "kilo-" means "multiply by 1000", so a kilometer is as long as 1,000 meters. These prefixes are added to various metric units but, due to their usefulness, have been adopted and added to other, non-metric units, such as "kilocubic feet per second" (for the flow rate of a liquid, much to Randall's chagrin when researching for his book What If?), "megadeath" (how many millions killed in an estimated nuclear blast), or the "millihelen" (the amount of feminine beauty needed to launch a ship). Most potentially confusing might be "kilo-/mega-/giga-/terabyte", which has competing definitions. However, they're not ordinarily added before number words to change their magnitude.

Taking "kilofive" to be a unit meaning 5,000, the population of East Hills, 6,000, can therefore be

expressed as 1.2 kilofives. But phrasing a number this way requires the listener to make excess calculations to understand it, so White Hat would probably get confused or annoyed.

It is somewhat common for metric prefixes to go after numbers in abbreviations. Well-known examples are "Y2K" for "year 2000", and "4K resolution" for "4,000 [pixels]". The number 5,000 may be abbreviated as "5K" in "5K resolution". However, the 'postfix' (suffix) may be intended to modify the implied but unstated unit, where there is an obvious one, or stand for the unit itself in such cases as the word "kilometer" (often abbreviated to /ˈkeɪ/(s), in common use, in phrases such as "5K run") or "kilopixel" (in this case referencing the horizontal resolution, as in 5120×2880 pixels, rather than prior usages such as the 1080 horizontal lines in the standard known as 1080p, or the total area pixel count in 'megapixel'/'gigapixel' image sensors), thus making it directly stand for a prefixed unit itself, as an adjunct to the standard common shortening of "kilos" for, usually, "kilograms". Saying "1.2 5K" could be even more awkward, liable to be misunderstood as "1.25k" (1,250) instead of the value of 6000.

In the title text, Cueball has apparently annoyed White Hat with his confusing expressions of numbers, but he doubles down, now directly including the word "score". He is riffing on the common expression, "give me one reason why..." but instead of simply asking for one reason, he asks for 50 milliscore reasons, or $50 \times 1/1000 \times 20$, which is equal to 1.

The comic might refer to the village of East Hills, New York. As of the 2020 census, it had a population of 7,284, or 1.214 kilosixes.

#2947: Pascal's Wager Triangle

June 17, 2024
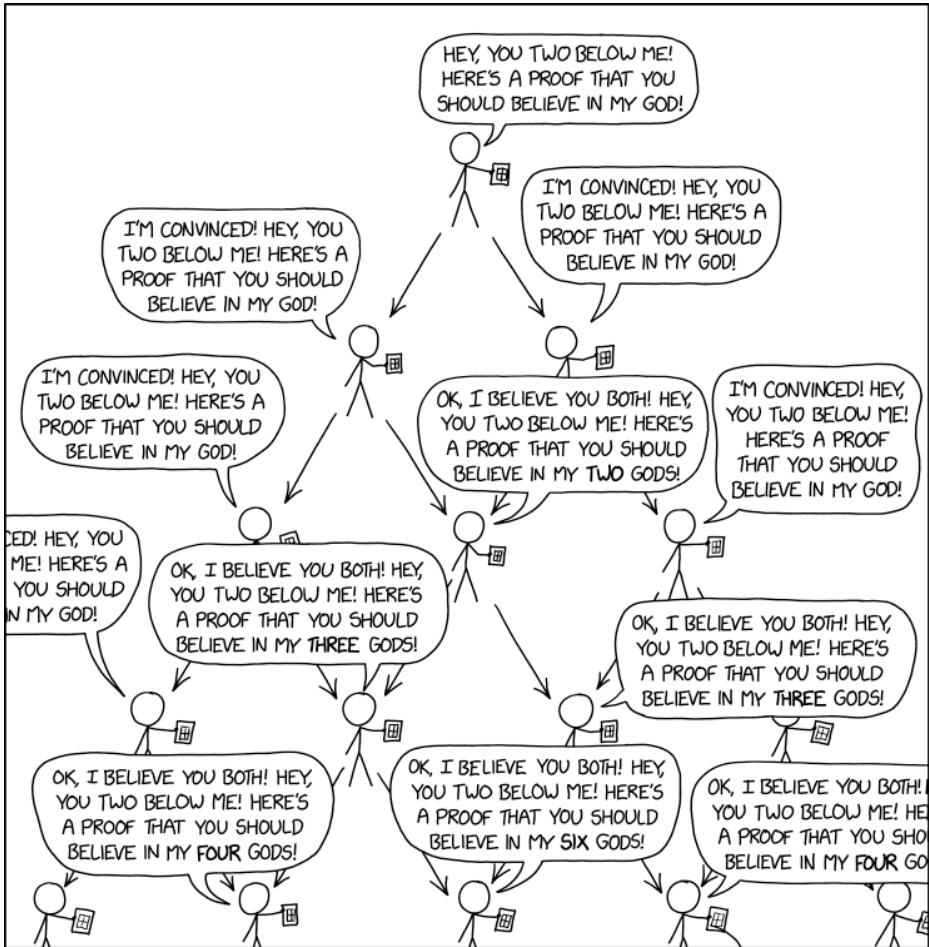
PASCAL'S WAGER TRIANGLE

In contrast to Pascal's Wager Triangle, Pascal's Triangle Wager argues that maybe God wants you to draw a triangle of numbers where each one is the sum of the two numbers above it, so you probably should, just in case.

Explanation

The comic is a conflation of Pascal's Wager and Pascal's Triangle. It's structured as a layout that emulates Pascal's triangle, an infinite triangle of numbers where the top number is 1 and each value below is the sum of the adjacent number(s) above it. The second row has two 1s (each the sum of the single 1 above), and the third row has a 1 (the sum of a single 1 in the second row), a 2 (the sum of both 1s above it), and another 1, and so on. It plays important roles in binomial expansion, probability theory, and other areas of math. While Blaise Pascal did not invent the triangle, it is named after him (an example of Stigler's law of eponymy).

Pascal's Wager is a philosophical argument proposed by the same Pascal. Essentially it says that if God exists, both the rewards for believing in God and the punishment for nonbelief are infinite; if not, the cost of belief and benefit for nonbelief are negligible. Therefore, if there is a finite possibility that God exists, however small, one should believe in God. One problem with that is that there may be more than one God to believe in, even if only one truly exists. Which one of all the possible Gods should you choose to believe in could be problematic, if the real God insists that you only believe in Him and punishes you for believing in any other gods (even if you somehow also believed in Him). A further problem is that committing to any particular belief in a deity is not a totally zero cost option, and thus affects your life in many needless ways if you subscribe to any particular

practice of religion not actually required by any extant god(s), even if any of them exist in the first place.

The comic merges the two Pascalian concepts: each Cueball is wagering his proof of a god or gods to the Cueballs below him, thereby creating Cueballs that believe in the sum of the number of gods of the Cueballs above them. In the second row, the two Cueballs each believe in one god, as intended by the original Cueball. However, in the third row, the Cueball in the middle interprets the two proofs offered to him as proving the existence of two gods. Theoretically, this expansion would continue for all integers as the triangle grows, giving rise to a belief in escalating numbers of gods going down and towards the middle of the triangle. This is clearly not the intent of the first Cueball, who simply offered a proof of his one god, but he has no control over the situation below him.

It is unclear why the Cueballs behave in this fashion, instead of treating all the proofs as proving the existence of the same god. Perhaps each one rewords their arguments for god(s) sufficiently to make them sound different than other gods. This is not without precedent. Scholars of comparative mythology believe that the religion of Proto-Indo-European peoples splintered into many disparate religions of Europe and West Asia; for instance, Dyeus phter (sky father) became Zeus in Greece and Jupiter in Italy.

This comic may be referencing a common counterargument to Pascal's Wager — that it works

equally well for any hypothetical god which offers eternal paradise for one action and eternal damnation otherwise. This can even include hypothetical gods with contradictory criteria for entrance into paradise. In this case, the Cueballs apparently chose to believe in all the deities they've heard of in order to cover their bases.

The title text suggests that everyone should draw a proper Pascal's Triangle, since there is a possibility that God wants you to do so, and if they do then the benefits of pleasing God or the costs of displeasing God could be high, whereas if they have no such desire then there is minimal cost to drawing one anyway. The failing of this logic is that God may have a positive preference for you not to draw a Pascal's Triangle (though at least according to the Catholic Church this is unlikely, as Pascal himself is on the way to beatification.)

Pascal's Wager was previously mentioned in the title text of 525: I Know You're Listening.

June 19, 2024

ELECTRIC MOTORS AND GAS ENGINES EACH HAVE THEIR PROS AND CONS.

ON ONE HAND, ELECTRIC MOTORS ARE CLEANER AND MORE EFFICIENT. ON THE OTHER HAND, ELECTRIC MOTORS ARE MORE POWERFUL.

SO IT'S HARD TO SAY WHICH IS BETTER OVERALL.
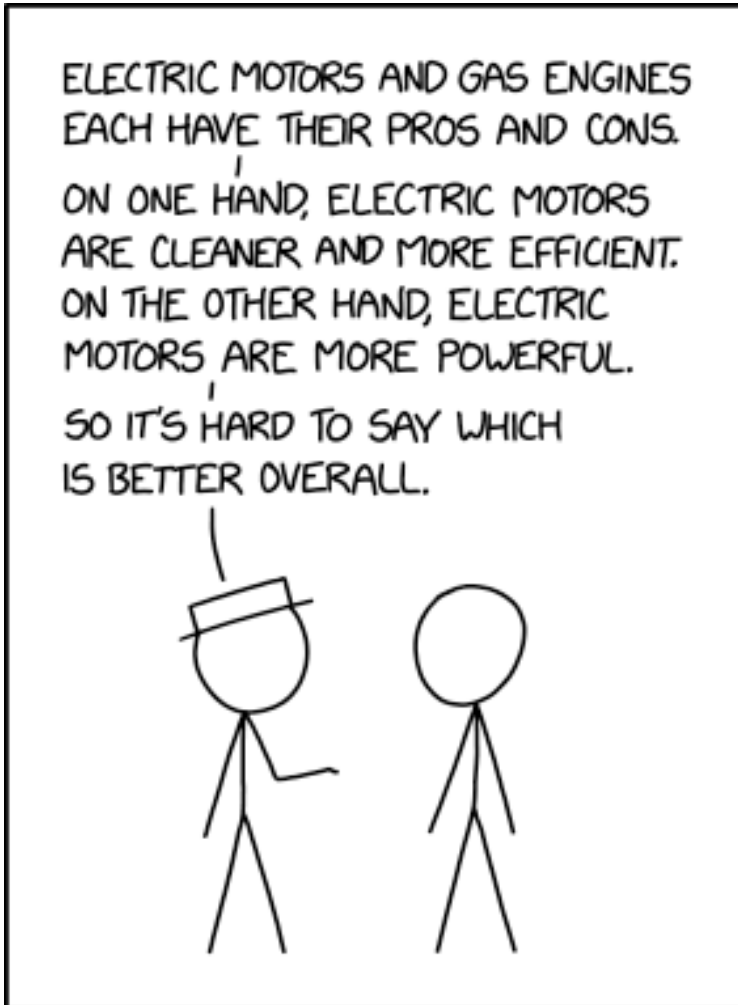
An idling gas engine may be annoyingly loud, but that's the price you pay for having WAY less torque available at a standstill.

Explanation

Internal combustion engines (ICEs) have long been the most common technology used to propel motor vehicles (usually in the specific form of reciprocating "piston" engines). In US vernacular, the most common vehicle fuel is known as "gasoline", or "gas" for short, leading to these engines being referred to as "gas engines". Gasoline is a product of petroleum refinement, leading to the name "petrol" being used in other dialects.

Electric motors would seem the more well-suited method for propelling a vehicle, and as early as 1885 were an actual form of motor car engine with which the fledgling internal combustion engine had to compete. Despite this early popularity, over most of the 20th century electric motors were sidelined in everyday car design, as supplying the electricity was considered to be impractical for most forms of transportation. Modern forms are rapidly rising in popularity, and now constitute 18% of all global vehicle sales. Randall is a strong proponent of electric vehicles (EVs).

In this strip, White Hat claims to be comparing the pros and cons of electric motors and gas engines. The joke is that every point he makes goes in favor of electric motors. Despite it being posed as a dilemma, it may be very clear which side of the debate White Hat is promoting. On the other hand, it may indicate that one of the things we might consider a pro in electric motors (the instantaneous power now available, exceeding that of

many non-electric engines) he would consider a problem — perhaps more accurately, a problem with the drivers of such vehicles — recklessly using the enhanced capabilities to accelerate to high speeds at all opportunities, whether safe to do so or not.

The strip offers the following points in favor of electric motors:

• "Cleaner and more efficient". ICEs produce and vent harmful combustion products and toxic chemicals, while electric motors produce no emission byproducts at the point of use. The efficiency of both gas and electric motors vary, but the typical ICE vehicle in the US converts around 25% of available energy into motion, while the typical electric vehicle is in the neighborhood of 80%. Even when considering inefficiencies in the source production and transmission and storage and release of energy, battery-driven electric vehicles are generally more efficient than internal combustion propelled vehicles.

It should be noted that all of this refers to the motors only, and ignores how the fuel and electricity are produced, or the wider environmental impact of the vehicle. Determining the overall environmental advantages of electric vehicles is a much more complex and involved calculation.

• "More powerful". Electric motors are able to deliver a lot of power from a small motor if an ample energy supply is available, and can do so 'on demand', often far

quicker than a fuel-powered engine that has to put its power through a gearbox in order to service a wide range of road velocities, from standstill to the eventual top speed. Due to battery limitations, short or partial runtime use cases (such as dragsters, hand tools, yard tools, toys and electric scooters) net the most benefit from the small size of a high-powered electric motor.

- "Annoyingly loud". ICEs, by their nature, produce significant noise. Despite noise attenuation measures such as mufflers, they contribute significantly to urban noise. Properly designed electric motors are nearly silent (even if the rest of the vehicle is not). In particular, turbocharger blowoff valves make particular noises that are completely lacking in an all-electric vehicle being driven at a similar performance level. This might legitimately be considered a problem, though, when everyone is used to a rapidly approaching vehicle providing a very noisy warning of its approach. EV makers have sometimes added fake ICE noises to appeal to older drivers, and in the U.S. and some other countries, EVs are required to have warning sounds at low speeds for pedestrian safety.

At highway speeds, the noise of tires against the road is much louder than a properly muffled ICE, so the intrinsic quietness of an EV's motor is close to irrelevant in that context.

- "WAY less torque available at standstill". ICEs need to continually operate within a specific range of rotational speeds for best power and fuel efficiency (although the

reciprocating engines used in most motor vehicles are still better than some others, such as gas turbine engines, in this regard), which means that a complex system of transmission gearing is needed to convert this motion into the specific speeds needed at the wheels. When starting from a standstill, this means that torque must be applied to the wheels relatively gradually to avoid stalling the engine. In addition, when a vehicle is standing still, the motor is typically idling at (very) low speed and must be sped up before it produces significant acceleration. Electric motors, in contrast, generally produce their peak torque when at a standstill. This results in electric vehicles having significantly better acceleration and engine responsiveness. Again, this could cause a legitimate problem with drivers changing from ICE to electric motors, because the new cars accelerate more than the driver is used to and provide different feedback. The audible clues of gear changes, whether from automatic or manual systems, are part and parcel of what many people have grown up with and come to rely on in anticipating what might need paying attention to.

It should be noted that White Hat is deliberately confining his arguments to electric vs gas motors rather than electric or gas-powered vehicles. Doing so ignores the basic reason why internal combustion vehicles have long been the dominant form of personal, motorized transportation: hydrocarbon fuels are a very dense and fairly easy to handle form of energy storage. Providing electrical power to a moving vehicle requires either that the vehicle remain in contact with a power line (as with

an electric train or a tram) or else to carry a high-capacity battery (and the ability to recharge that battery in a reasonable amount of time, while stationary). More popular in the USA is a hybrid system, where a combustion engine provides at least some of the power to an electric motor, which was impractical until comparatively recently. Other methods, such as hydrogen fuel cells (a form of "combustion" that can be used more directly to form electricity), have been proposed, but remain experimental or niche, due to various barriers to adoption.

A more comprehensive comparison would include many more factors, both against and in favor of electric cars.

Issues raised with electric vehicles typically include:

- Higher cost of purchase (primarily due to the cost of batteries and, in the USA, now a 100% tariff on Chinese EVs), although partially offset by lower costs of operation
- Long charging times compared to refilling a gas tank (there are some approaches which mitigate this by operating either very high-powered chargers or a battery swap model, rather than charging in-car, but these are not widely adopted)

  The significance of this depends on individual situations. Most EV drivers charge primarily at night, and many drivers don't mind a charging break on long trips.

- Relatively limited range. This is less of an issue in

modern times, as many modern EVs have ranges of (200-500 miles per charge as of 2024, similar to the range of a typical ICE vehicle.

- Shortened range in hot weather and significantly shortened range in cold weather (while all vehicles have this problem, it's more pronounced in EVs compared to ICEs)

- Limited charging infrastructure compared to the prevalence of fuel stations

Because many drivers can charge at home, fewer public chargers are needed than for gas cars.

- Higher vehicle weight, and resulting higher particulate emissions (from tires, but not brakes, because EVs use of regenerative braking reduces wear on their traditional brakes)

- Reliance on some mineral and metal extraction industries (e.g., lithium) with capacity that lags the recent increased demands for EVs

- Increased demand on electricity production

- Lower reliability(data possibly skewed by the newness of EV models).

Other real pros of electric cars are also not mentioned:

- Lower total cost of ownership (TCO), due to cheaper fuel and lower maintenance costs.

- Can potentially "fill" them at home or while parked without having to stay with them (partially negates the

issue of "long charging times".)

- Lower carbon footprint, and reduced dependence on the fossil fuel industry

Rapidly evolving technologies, government policies, and economic realities are changing the relevance and seriousness of these points over time. As of the publication of this strip, the "pros" of EVs do not seem to be universally convincing, as ICEs remain far more popular than EVs in most countries (EVs constitute a majority of new vehicle sales in only four countries: Norway, Iceland, Sweden and Finland). That said, EVs didn't exist as a viable industry 20 years ago, so the current reality reflects rapid and ongoing growth, suggesting that the advantages of EVs are gaining increasing recognition and understanding.

The degree of adoption is also likely to impact the viability of different vehicle types. Infrastructure in most countries has long been built around an assumption of ICEs, so things like fueling stations and ICE-qualified mechanics have traditionally been widely accessible. As EVs becoming increasingly dominant, this could shift, with EV charging infrastructure becoming easier to find than ICE fueling stations, and ICE mechanics potentially becoming more difficult to find. There's typically a certain level of inertia in the adoption of any new technology.

In the EU, the sale of new ICE cars is banned from 2035 in an effort to move to EVs, and other jurisdictions are adopting similar policies.

Especially in the United States, this topic is highly contentious for political, economic, engineering, and tribal reasons (as a quick look at the edit history of this page will confirm).

#2949: Network Configuration

June 21, 2024
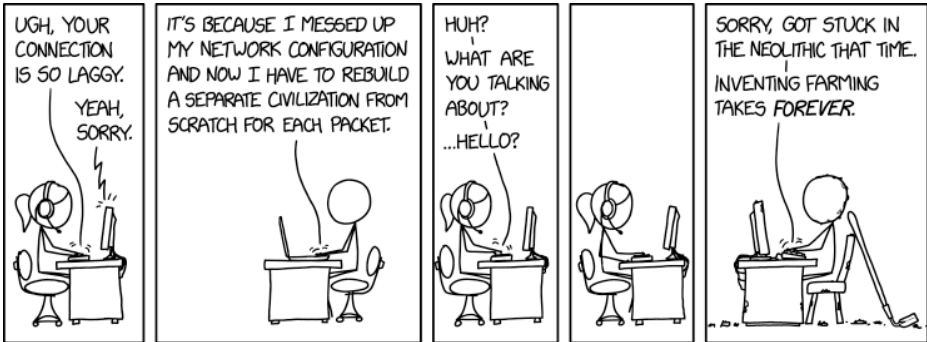
If you repeatedly rerun the development of technological civilization, it turns out that for some reason the only constant is that there is always a networking utility called 'netcat', though it does a different thing in each one.

Explanation

In this comic, Cueball takes an uncommon networking bug - needing to establish a fresh connection for each packet sent - to the extreme. Instead of merely redoing the appropriate handshakes for data transfer, he is reconstructing the entire history of human civilization each time. As this originally took multiple millennia, doing it for every network packet would make communication extremely slow; in modern networking, we send and receive thousands of packets every second.

Randall may be using a double meaning of the word "rebuild." Instead of just rebuilding his network settings - starting fresh with a clean setup - he is rebuilding civilization itself from scratch, an extreme type of "first principles thinking."

In the last frame of the comic, Cueball looks shaggy and dirty and has a grub hoe behind him, making it clear he is performing these tasks in real life just to get his network working again. He says the network packet was stuck in the Neolithic era, the final period of the Stone Age that marked the transition from hunter-gatherer lifestyle to one of settlement. Apparently, Cueball had to go through the effort of inventing farming (one of the developments of the Neolithic Revolution) to keep communicating with Ponytail. He has also had to build himself a new wooden chair (and possibly desk), and hasn't yet got to the point of developing a notebook computer, so is using an under-desk tower PC connected

to a chunky monitor. Presumably his previous equipment and furniture were lost in resetting to the Neolithic, though this seems to have been a localized effect, given that Ponytail appears unaffected.

"Inventing farming takes forever" references the actual rather complex process of inventing farming. First, we needed the last Ice Age to end - around 11,000 years ago - to create suitable climatic environments for agriculture. Then we required advancements in plant cultivation, animal domestication, and tool development - lots of time and experimentation involved there. And the transition from hunter-gatherer societies to sedentary farming communities also needed significant social and cultural adaptations (e.g., new organizational structures).

Randall Munroe is familiar with the popular creative nonfiction topic of what it takes to rebuild civilization, the subject of a book he blurbed on its cover, How to Invent Everything, by Ryan North, fellow cartoonist.

- The topic of rebuilding a civilization from scratch was also referenced in comic 1380: Manual for Civilization and in the title text of 2347: Dependency.

The title text discusses netcat, a simple utility to make a TCP connection which comes in annoyingly incompatible nc.traditional and nc.openbsd varieties.

In addition, the tendency for civilizations to independently develop netcat may be an allusion to The Hitchhiker's Guide to the Galaxy, in which 85% of all

planets invariably develop a cocktail whose name is, by pure coincidence, a phonetic homophone to "gin and tonic", such as the Jynnan tonnyx, while varying wildly in composition. The word "netcat" is a composite of "net" (most likely standing for network each time, although could relate to some form of mesh/trap, a topology or an amount less any deductions), and "cat", which references the Unix utility cat, or it may be an abbreviation (for example for catalogue, category, catalyst, catastrophe etc.), or even actually referring to a cat. The various possible combinations could encompass a wide variation in function of similarly named processes.

#2950: Situation

June 24, 2024

HYDROGEN-FILLED SCOUT AIRSHIP FOR ICEBERG SPOTTING

SOVIET-ERA NUCLEAR REACTOR UNDERGOING A TURBINE TEST

BRIDGE PRONE TO AEROELASTIC FLUTTER IN HIGH WINDS

UNSINKABLE OCEAN LINER
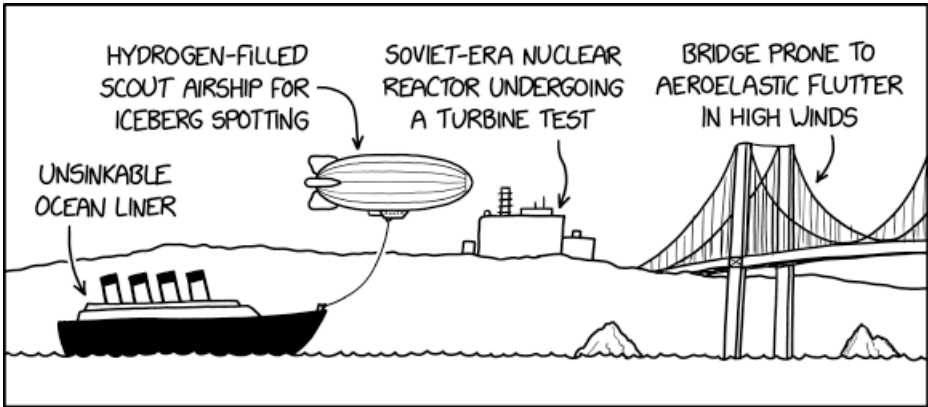
IN RETROSPECT, WE SHOULD HAVE NOTICED HOW NERVOUS THE SITUATION WAS MAKING THE ENGINEERS.

We're right under the flight path for the scheduled orbital launch, but don't worry--it's too cold out for the rockets to operate safely, so I'm sure they'll postpone.

Explanation

This comic depicts a situation involving multiple pieces of infrastructure: a ship, sailing towards icebergs, which is tethered to an airship flying next to a power plant towards a bridge. Each of these are labelled with details that clearly reference famous disasters, all of which were caused (at least in part) by design failures. All of these incidents are common case studies for engineers studying how things can go very wrong. The implication is that, by putting them all together, most engineers would be highly concerned with the potential for catastrophe.

As illustrated, it appears that the ship is about to sail under the bridge, while the airship will fly over it, causing the tether between the two to snag the bridge unless the airship descends sufficiently before then. It is not clear how or if the reactor will contribute to the resulting incident.

#2951: Bad Map Projection: Exterior Kansas

June 26, 2024
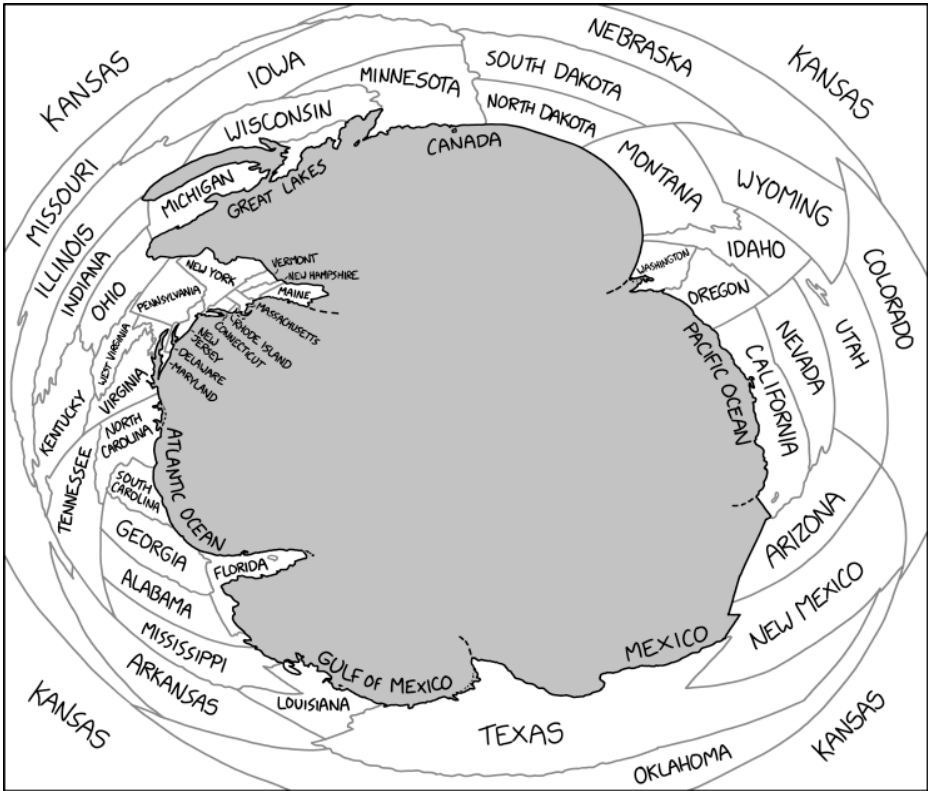
BAD MAP PROJECTION #45:
EXTERIOR KANSAS

Although Kansas is widely thought to contain the geographic center of the contiguous 48 states, topologists now believe that it's actually their outer edge.

Explanation

This is the seventh comic in the series of Bad Map Projections displaying Bad Map Projection #45: Exterior Kansas. It came about 11 months after the sixth 2807: Bad Map Projection: ABS(Longitude) (#152), and was followed 3,5 months later by 2999: Bad Map Projection: The United Stralia (#102).

This comic portrays an unusual projection of a map of the contiguous United States based loosely on an azimuthal projection. Maps of individual countries are common, especially in academic settings. It is typical for such maps, which only display a limited area of the globe, to use a projection that does not severely distort the shape of the country or its internal borders, but a country that is large enough (as with the United States) will always noticeably suffer from certain distortions of at least one element chosen from distances, areas or angles. This usually occurs at its extremities (though some projections can be made more faithful to its extremities at the expense of distorting its interior).

Here, however, Randall has opted for a much different projection. Rather than placing the geographical center of the country in the middle and the borders on the outside, this map has gone the opposite direction, with the border of the US toward the center, and the geographical center of the contiguous US (Kansas) and surrounding states distorted to surround the entire map. This, understandably, results in the shape of both the

national and state borders being largely unrecognizable as it effectively puts every bit of the chosen map features out towards the distorted extremities. Much of the internal area of Kansas itself (should one wish to display further internal features) may be located far beyond the comic's edges, perhaps even to infinitely far away on the projected plane.

If Alaska and Hawaii were present in this map and represented in geographically accurate locations (as opposed to inset, as is common in many maps of the United States), Alaska would in the upper right of the empty space, between Minnesota and Washington, while Hawaii would be in the center to the right, off the coast of California. Both would be rather small, with Hawaii particularly compressed (to an extent dictated by the exact projection method used). Additionally, if all 50 states were included, the geographical center would be further to the northwest, resulting in an "Exterior South Dakota" projection.

The title text refers to the fact that the geographic center of the contiguous United States is within Kansas. This map projection instead causes Kansas to show up as the exterior of the US, which makes it the outer edge.

The statement that topologists now believe it's actually their outer edge plays with the notion that map projections influence your perspective on the world, as it is known to be the case with more familiar examples like Mercator vs. Gall-Peters projections, or world maps with the South Pole on top and so on. Similarly, or so the

claim goes, any notions of interior and edge may just be a matter of perspective.

If you were to enclose a small square in four walls, but define this to be the outside, you'd effectively create a roofless building of which the floor area encompasses almost the entire surface of the Earth (minus the small square) - see So Long And Thanks For All The Fish by Douglas Adams for a classic example of this gag. Randall has always been fond of exploring how map projections influence our perspective both in a parodistic way and by playing it straight, e.g. in: 503: Terminology, 977: Map Projections, or 2838: Dubious Islands

#2952: Routine Maintenance

June 28, 2024
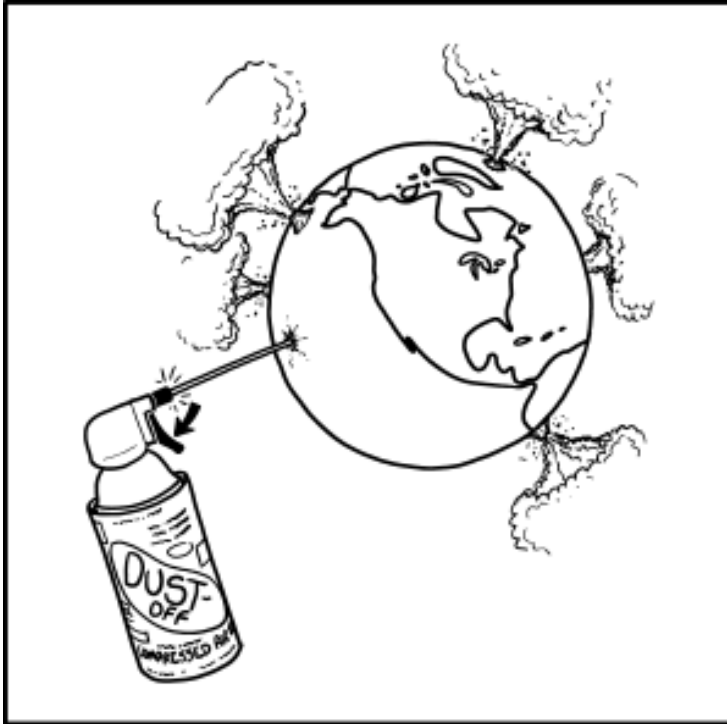
I KNOW ROUTINE MAINTENANCE IS IMPORTANT, BUT I HATE HOW WE ALL HAVE TO TAKE SHELTER FOR 48 HOURS EVERY YEAR WHILE THEY FLUSH OUT THE EARTH'S MAGMA SYSTEM FOR CLEANING.

The worst was the time they accidentally held the can upside down and froze all the Earth's magma chambers solid.

Explanation

This comic is almost certainly a reference to chapter 9 of the book The Little Prince by Antoine de Saint-Exupéry. On the first page the following quote can be found: "On the morning of his departure he put his planet in perfect order. He carefully cleaned out his active volcanoes."

A recommended routine maintenance step for many electronics, such as desktop computer towers, is to remove the buildup of dust on a regular basis. This can help prevent the electrical components from overheating, and lengthen their lifetime. To make this job easier, safer, and cleaner, there exist cans of high-pressure gas, as depicted, which force through high-flow gas to displace the dust. (Attempting to do this with air from the lungs would be less effective, may add unintended moisture to the electronics, and could result in a face-full of dust.[citation needed])

The comic suggests that a similar maintenance step is performed on the Earth itself, blowing gas into the Earth to force out the dust from its magma chambers. However, filling the atmosphere with dust would be unhealthy and fatal to living beings, so as a safety measure everyone would have to take shelter.

This may be a reference to one theory about the K-T extinction event — that a crashing meteor sent so much dust into the air that it killed off many plants and animals, including all non-avian dinosaurs, in a much

wider area than that directly affected by the initial impact. Those lineages that chanced to survive the global effects must have been able to escape the worst of the disrupted ecosphere while the worst of the atmospheric effects subsided, and were then able to exploit various newly vacant (and/or changed) environmental niches. (This would include our own mammalian ancestors, and the avian dinosaurs that led to todays birds; some of them may, perhaps, have survived by already being more inclined/suited to living in burrows.) However, this dust cloud would have lasted longer than the 48 hours suggested in the comic.

The image suggests that the "routine maintenance" for Earth would involve using the Hawaii hotspot (possibly via its most active volcano, Kilauea), as the point to insert the high-pressure gas, causing volcanoes to erupt in Iceland, the Aleutian Islands or the Kamchatka Peninsula, the Andes, and elsewhere; the two geographically-indeterminate plumes may represent Italy and Indonesia.

The title text mentions using the can upside-down, and this freezing solid the magma chambers. Pressurized canisters of "air", as with similar aerosol sprayers, contain a propellant gas that condenses into a liquid when compressed. When the spray valve is opened, the release of pressure allows some of the liquid to evaporate and take the place of the released gases, or become some of the gas subsequently released (or all of it, if its purpose is not to spray other contents). The transition of the propellant liquid/gas from dense liquid to space-filling

gas requires it to 'boil off', this process needing to pick up heat (or 'enthalpy') energy. Under typical operation, the cooling liquid/gas takes heat from the general mass of the can itself as it tries to attain thermal equilibrium. As a result, the can (and the expelled gases) will be cooled a little. Then (ultimately) heat will also be taken from anything touching or surrounding the slightly cooled can and its spray. This is precisely how a purposeful refrigerant acts, either as a one-time process or as a reversible cycle where re-pressurizing a suitable gas can 'release' heat (the heat/enthalpy of condensation) at the 'hot side' of a refrigerator, returning the gas in the system to liquid that it can later let boil again and cool the 'cold side' of the refrigerator.

It is not normally useful for such a can to allow the liquid propellant-in-waiting to exit the container, as it would waste its usefulness as a source of pressure once it does. But by holding the container the wrong way up (which way that is being dependent upon its design, and intended use...) the pressurized contents push the liquid out via the nozzle's stream. The now exposed propellant is now free to evaporate into the air at atmospheric pressure, typically much lower than the constraints it had within the can, after landing directly upon whatever the can was sprayed at. The resulting demand for heat energy (much more rapid than normal, and likely concentrated upon a much smaller target than the can itself represents) produces a greater localized drop in temperature and can lead to freezing nearby liquids (which may or may not be intended/useful). Of course, the total 'cooling effect' of

such a can does not change, depending upon how it is (mis)used, it merely changes the extent (and lifetime) of application, and how extreme the temperature change may be within a much more limited 'liberation' of its cooling ability.

Spraying "canned air" with the can inverted is a party trick used to very quickly cool beverages, being able to bring them down from room temperature to ice cold in seconds if performed correctly.

Some spray cans are designed to freeze objects, e.g. to help in plumbing repairs or finding overheating electronic components. Freeze spray is also used in medical applications. These require careful use to avoid unintentionally (or intentionally!) damaging exposed skin or objects that can be damaged by local temperature differences, such as glass.

Given the location of the planetary-scale dust-busting 'air canister', it may be considered confusing which 'way up' is the correct orientation, given that Earth-gravity would be pulling the contents sideways (however that changes what the nozzle ends up ejecting from the can itself). But such a large can would also have its own significant internal 'can-centric' gravity that possibly (depending upon how full of still-liquid propellant it is) exceeds that of the Moon, possibly letting all the denser liquid hold itself into the centre of the canister, even against the nearby Earth's gravity. Being significantly closer to the Earth than the Moon is, this can could also be a far greater influence upon Earth's own tides (not alluded to

in the comic), making the dusting of the atmosphere or the freezing of some of its magma secondary issues to the sheltering population. But if magma froze to the extent of disrupting or disabling the Earth's magnetic field, this "secondary" issue could quickly become primary, even existential.

Three comics after this one Randall released 2955: Pole Vault, where the Earth is being punctured by the tip of a pole vaulting stick causing the Earth to burst like a ballon. That idea seems to be similar, but opposite the one from this comic. With so few days between the releases there might have been some similar thoughts behind the creation of both.

#2953: Alien Theories

July 01, 2024

ANNOYINGLY, THE ALIENS TURNED OUT TO BE REALLY INTO UFO CONSPIRACY THEORIES.

They originally came here to try to investigate our chemtrail technology, and got increasingly frustrated when all their samples turned out to just be water ice with trace amounts of jet exhaust.

Explanation

This comic is making fun of conspiracy theorists who believe alien life is spying on Earth, by making aliens who are actually in contact with Earth into conspiracy theorists themselves.

A cultural phenomenon on Earth is based on the concept that unidentified flying objects (UFOs) represent visitors from extraterrestrial civilizations (aliens), to the extent that "UFO" may be considered entirely synonymous with "alien spacecraft", rather than the more basic truth of just not having yet been recognized as anything in particular. In the USA, these are now officially termed "unidentified anomalous/aerial phenomena" (UAPs), in an attempt to mitigate this type of automatic association, although there are already those who readily adopt the new term as equally indicative of their old opinions.

Being unidentified, there could be many trivial reasons (and a few still very interesting non-trivial ones) that could be the truth of any particular observation, without needing to invoke the presence of aliens. But those who believe that UFOs/UAPs are extraterrestrial spacecraft may respond to those who reject this idea with the line, "These objects have capabilities superior to ours, it would be foolish not to investigate," especially in cases where astounding speeds and maneuverability are apparently observed (however much they may be more trivial phenomena, such as camera movement, glints off lenses, or other optical effects) or conveyed by uncorroborated

witness statements

This comic attributes the "foolish not to investigate" line to bona fide flying saucers who have chosen to make direct communication with Earth, represented by Cueball (who seems to calmly accept their presence). Whereas skeptical humans may confront UFO believers with evidence that their belief in aliens is unfounded, and argue that it is pointless to continue to promote theories (conspiracy or otherwise) about them, Cueball confronts the flying saucers with evidence that aliens do exist (in the form of themselves), and therefore promoting further unsubstantiated theories would seem redundant in the first degree.

The aliens we see would surely know which vague terrestrial observations were actually of themselves, and could certainly confirm the existence of themselves in the first place, but seem to conclude that various other 'unidentified' observations on Earth are mysteries worthy of their own wild speculation, concluding that anything that doesn't conform to their own known abilities must be an (additional) alien visitation of some kind. Cueball is annoyed that the occupants of the flying saucers maintain their unfounded beliefs despite lack of solid evidence. Possibly these are the same aliens who are also shown to be credulous regarding cryptids. They reflect the situation of (human) UFO believers, who maintain their beliefs despite the absence of evidence. The aliens also maintain their beliefs in such tenuous observations, despite even the depicted aliens themselves maintaining that those other events were nothing to do with them.

(Though human presumptions about the existence of aliens would, as it turns out, be shown to be correct in cases such as this particular encounter.)

The title text reports that the extraterrestrials have had no better luck finding evidence for conspiracy theories about "chemtrails" (vapor trails) than have humans, concluding that they are just water/ice particles after testing collected samples. Chemtrails are supposed clouds of gas or other substances deployed by commercial airplanes, which are used to mind-control the population or in some way alter the human population or the environment (depending on who you ask). They have been mentioned before on xkcd. Ironically the origin of the ice mentioned in the title text is jet exhaust — if you burn a hydrocarbon (such as the components of jet fuel) the main products will be carbon dioxide and water. At the temperatures and pressures it is released, the water will mostly turn to ice as it nucleates under the local temperature and pressure conditions. However, a significant fraction will later sublimate.

#2954: Bracket Symbols

July 03, 2024

BRACKET SYMBOLS
AND WHAT THEY MEAN

( ) REGULAR PARENTHESES
FOR SETTING STUFF ASIDE

[ ] SQUARE BRACKETS
(MORE SECURE)

{ } THIS STUFF IS EXPENSIVE
SO BE CAREFUL WITH IT

" " SOMEONE IS TALKING

' ' SOMEONE BRITISH
IS TALKING

< > AN ANIMORPH IS TALKING

« » A FRENCH ANIMORPH
IS TALKING

| | I'M SCARED OF NEGATIVE NUMBERS
BUT THESE SIGILS WILL PROTECT ME

* * _ _ / / I HAVE A FAVORITE
MONOSPACED FONT

~~ I'M BEING SARCASTIC AND I HAD
A TUMBLR ACCOUNT IN 2014

[([{( )}],)] THESE PYTHON FUNCTIONS
ARE *NOT* GETTING ALONG

⌊ ⌋ HELP, I'M A MATHEMATICIAN
TRYING TO WORK WITH ACTUAL
NUMBERS AND THEY'RE SCARY

∫ ⌡ WHY ARE YOU TRYING
TO READ MY VIOLIN?

| ⟩ DON'T STOP HERE—THIS
IS QUANTUM COUNTRY

"" means "I edited this text on both my phone and my laptop before sending it"

Explanation

Brackets, also called parentheses, are typographical symbols used to delimit a section of text. Unlike most typographical symbols, brackets usually come in pairs, and the end bracket is typically the mirror image of the start bracket.

This comic shows a variety of (mostly) real bracket symbols, along with Randall's description.

The title text includes different kinds of quotes, including the ASCII " and ' as well as the Unicode " and " (which have both an opening and closing version).

By default, iOS uses the latter curly quotes, while Windows uses the former straight quotes (an OS-level application of the "smart quotes" described above). Editing the same text on both an iPhone and a Windows computer, in circumstances with a different approach to such general auto-replacement, can leave both types of quotes in the text.

Parentheses are a running joke on XKCD. Previous parenthetical comics include:

- 297: Lisp Cycles - referencing the Lisp programming language's use of parentheses
- 312: With Apologies to Robert Frost - the punchline is a close parenthesis
- 541: TED Talk - about ending parenthetical statements

with emoticons

- 859: (- which has an open parenthesis with none to close it
- 1052: Every Major's Terrible - making fun of Computer Science as a major for its tedious use of matching parentheses

#2955: Pole Vault

July 05, 2024
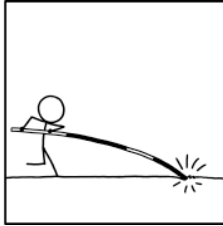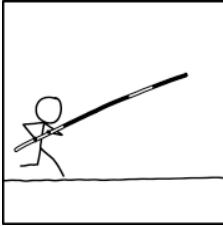
Ugh, and we JUST went through this yesterday with javelin.

Explanation

In the comic, Cueball is making a run as part of a pole vault competition. However, when he tries to plant the pole to make the jump, the tip pierces the surface of the Earth, causing it to pop and violently deflate, like a balloon.

This does not normally happen during a pole vault,[citation needed] but the title text suggests that the same recently happened during a javelin competition, presumably when one of the spears pierced the surface in a similar manner to Cueball's pole. No explanation is provided for how the Earth was patched or re-inflated, but apparently the problem was solved in a single day, without needing to cancel the event, suggesting that this is a normal occurrence.

The comic may be inspired by the upcoming Paris Olympics, and the geographical location of the burst is indeed somewhere in the European continent. The view of the ragged and deflating Earth suggests the possible epicenter of the burst has more of a vague relationship with that area than it might to Randall's own location in the US (the other 'logical' definite setting he might use). The comic precedes any of the actual official competitions (or indeed the official Opening Ceremony) by three weeks, but perhaps this event (and the javelin one) occurred at one or other of the attending nations' training camps, or national trials for a local athletics squad, already established in the general region.

Alternatively, this is simply depicting future events.

Three comics before this one Randall released 2952: Routine Maintenance, where the Earth is being subject to a routine maintenance by pushing the tip of a high pressure canister into Earth and blowing air into Earth to expel debris from inside Earth's volcanoes. That idea seems to be similar, but opposite to the one from this comic, in that here the Earth is a soft stretchable surface enclosing a pressurised gaseous interior, whereas in the previous comic it was a hard shell with gas filled cavities open to the exterior. With so few days between the releases there might have been some similar thoughts behind the creation of both.

#2956: Number Line Branch

July 08, 2024
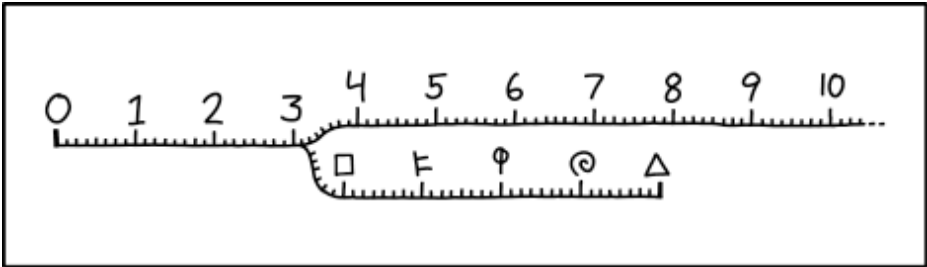
GOOD NEWS!

AFTER THOUSANDS OF YEARS, MATHEMATICIANS
HAVE FINALLY OPENED A SECOND BRANCH ON
THE NUMBER LINE TO REDUCE CONGESTION.

Attention all passengers: This is an express sequence to infinity. If your stop is not a power of two, please disembark now.

Explanation

This comic likens the number line to a line of a railroad or subway system. These often have branches where different trains continue on to a different destination, with different stops along the way, or travel on parallel lines to allow faster trains to bypass slower ones. In the number line, one branch (presumably the original) contains ordinary integers, while the newly opened branch consists of some completely different numbers, denoted with various symbols as an analogue to those we use as digits. The branches seem to split around π. The new branch maintains the same distance between numbers as the 'normal' one (as far as it goes) but, due to a longer initial curve away from the junction, the digits of the new branch are also consistently offset slightly to the left from the horizontal positions of the respective digits of the normal branch.

The new branch ending with a bold mark at Δ (whereas the original number line fades out after 10) suggests that it is the end of this branching sequence. Mathematicians, apparently, could only afford to construct 5 additional numbers, or their research hasn't yet found other numbers. The branch may have been intended to run much further, but it was possibly scaled back due to budget overruns and cutbacks.

The title text makes a parallel between a train stopping at a station and a numerical sequence "stopping" at a number – that is, taking it as a value. It's a spoof of

announcements that are typically made on trains, so that passengers can confirm that they're on a train that goes to their desired station; an "express train" typically makes fewer stops so it can serve the most popular stops and reach its final destination sooner. In this case, the express train only stops at powers of 2; presumably the "local" train stops at every integer. Powers of 2 are 2, 4, 8, 16, 32, ..., 2n, such that the interval between stops grows exponentially larger.

Mathematically, an express train like this would get to its scheduled stops much faster, but it would not actually have any fewer stops overall. Mathematicians that study infinities generally regard all "countably" infinite sets as being the same size (containing the same number of elements). Infinity is not a fixed value; rather, it's the concept of "does not end", so it's paradoxical to try to take a train to a destination that is, by definition, not a single destination. By way of analogue, it's akin to promising to stop hitting your little brother only after you've done so forever.

This same property of infinite numbers (that all countably infinite sets are the same size) also means that adding the new branch does not increase how many numbers the system can handle. This is similar to the phenomenon of induced demand in transit, where expanding the capacity for a road or train system frequently results in demand rising back up to capacity, becoming just as congested as it was before.

A fictional number was previously shown in 899:

Number Line ("gird"), and fictional numerals were shown in 2206: Mavis Beacon. Similar treatment of mathematics as public infrastructure was seen in 2735: Coordinate Plane Closure.

The comic may be a late reference to the opening of the Silver Line extension on the DC metro subway system, which was under construction for 12 years before being opened to the public in 2022.

#2957: A Crossword Puzzle

July 10, 2024

DOWN

1. GAME FEATURING "A RECKLESS DISREGARD FOR GRAVITY"
2. $1010101010101010101010_2 \rightarrow 16$
3. GOOGLE PHONE RELEASED JULY '22
4. IT'S FIVE TIMES BETTER THAN THAT *OTHER* STEAK SAUCE
5. ToHEX(43690)
6. FREDDIE MERCURY LYRIC FROM *UNDER PRESSURE*
7. FULL-SIZE AUDI LUXURY SEDAN
8. FAST PATH THROUGH A MULTIPLE CHOICE MARKETING SURVEY
9. 12356631 IN BASE 26
10. VIRAL JIMMY BARNES CHORUS
11. RUBY RHOD CATCHPHRASE
12. badbeef + 9efcebbb
13. IN WET LEG'S *UR MUM*, WHAT THE SINGER HAS BEEN PRACTICING
14. REFRAIN FROM NORA REED BOT
20. MARIO BUTTON PRESSES TO ASCEND MINAS TIRITH'S WALLS
24. VERMONT HISTORIC ROUTE NORTH FROM BENNINGTON
26. HIGH-BUDGET VIDEO GAME
28. UNORTHODOX TIC-TAC-TOE WIN
29. STRING WHOSE SHA-256 HASH ENDS "...689510285e212385"
30. ARNOLD'S REMARK TO THE PREDATOR
31. THE VOWELS IN THE FIRE SALAMANDER'S BINOMIAL NAME
32. JANET LEIGH *PSYCHO* LINE
34. SEVEN 440Hz PULSES
37. AUDI LUXURY SPORTS SEDAN
38. A HALF-DOZEN EGGS WITH REASONABLY FIRM WHITES
39. 2-2-2-2-2-2 ON A MULTITAP PHONE KEYPAD
40. ·— ·— ·— ·— ·— ·—
42. RATING FOR CHINA'S BEST TOURIST ATTRACTIONS
43. STANDARD DRUMSTICK SIZE
45. "THE RAIN/IN SPAIN/FALLS MAIN-/LY ON THE PLAIN" RHYME SCHEME

ACROSS

1. FAMOUS PVT. WILHELM QUOTE
11. IPv6 ADDRESS RECORD
15. "CIPHERTEXT" DECRYPTED WITH VIGENÈRE KEY "CIPHERTEXT"
16. 8mm DIAMETER BATTERY
17. "WARTHOG" ATTACK AIRCRAFT
18. EVERY THIRD LETTER IN THE WORD FOR "INABILITY TO VISUALIZE"
19. AN ACROSTIC HIDDEN ON THE FIRST PAGE OF THE DICTIONARY
21. DEFAULT PAPER SIZE IN EUROPE
22. FIRST FOUR UNARY STRINGS
23. LYSINE CODON
24. 40 CFR PART 63 SUBPART CONCERNING ASPHALT POLLUTION
25. TOP BOND CREDIT RATING
26. AUDI COUPE
27. A PAIR OF SMALL REMOTE BATTERIES, WHEN INSERTED
29. UNOFFICIAL HOWARD DEAN SLOGAN
32. A 4.0 REPORT CARD
33. THE "HARLEM GLOBETROTTERS OF BASEBALL" (VOWELS ONLY)
34. 2018 KIEFER SONG
35. TOP MINOR LEAGUE TIER
36. REPLY ELICITED BY A DENTIST
38. ANAA'S AIRPORT
41. MACAULAY CULKIN'S REVIEW OF AFTERSHAVE
43. MARKETING AGENCY TRADE GRP.
44. SOARING CLIMAX OF LINDA EDER'S *MAN OF LA MANCHA*
46. MILITARY FLIGHT COMMUNITY ORG.
47. ICONIC LINE FROM *TARZAN*
48. EVERY OTHER LETTER OF JIMMY WALES'S BIRTH STATE
49. WARTHOG'S POSTSCRIPT AFTER "THEY CALL ME *MISTER* PIG!"
50. MESSAGE TO ELSA IN *FROZEN 2*
51. LOLA, WHEN BETTING IT ALL ON BLACK 20 IN *RUN LOLA RUN*

Hint: If you ever encounter this puzzle in a crossword app, just [term for someone with a competitive and high-achieving personality].

Explanation

This crossword may seem extremely difficult, with questions covering a wide variety of trivia, linguistics, mathematics in various forms, alongside wordplay typical of crossword puzzles. But the joke is that every single letter of every single answer is "A". The name of this comic, "A Crossword Puzzle", is a double entendre which could, in itself, be considered a cryptic clue; the "A" can be interpreted both as the indefinite article "a" and as an identifier saying that this crossword puzzle is specifically an "A" puzzle, due to the answer being all "A"s.

The title text is a play on a "type A" personality. The term for someone with a competitive and high-achieving personality is "Type A". In the context of the title text, this answer is a hint that the entire puzzle can be completed in a crossword-solving app by typing the letter A repeatedly.

Across[edit]

Down[edit]
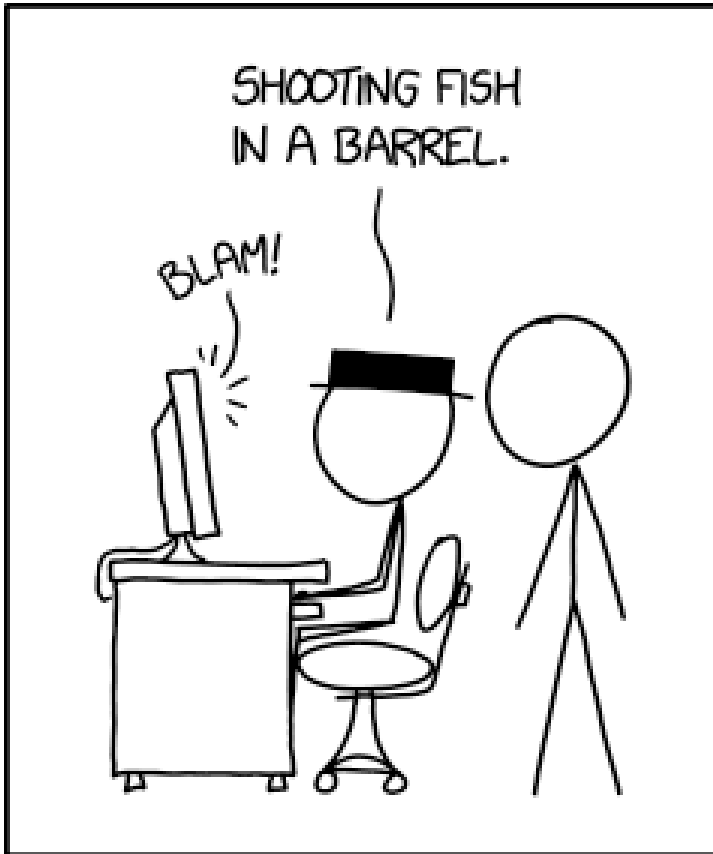
Anadromous fish are more vulnerable in rivers, since the lack of salt means you can quickly crack passwords using rainbow trout tables.

Explanation

Remote code execution is a type of software exploit that takes advantage of a bug to allow a remote user of a computer application to make it run code that it was not intended to execute. For example, a webserver with such a bug might allow a user of a web page to make it run a program that deletes system files or displays private information.

The joke arising from this comic is that if you remove the "e" from "code", you get "remote cod execution". This refers to killing ("executing") codfish remotely, using an exploit in a network application that allows one to view and interact with the hatchery.

The title text contains a pun on rainbow tables, referring to rainbow trout, one type of which (steelhead) is anadromous (migrating up rivers to spawn -- salmon are another well known example). Rainbow tables are used when trying to crack hashed passwords; these are files with a carefully pre-computed selection of passwords and their corresponding hash values, which can be used to more efficiently recover passwords that are provided only in their hashed form. To prevent rainbow tables from being usable in this way, most modern password systems use "salt" — an extra random string that gets appended to the password before hashing so the same password will potentially have many different hashes, and it becomes infeasible to recover it even with the acceleration offered by rainbow tables. An additional pun is that rivers

contain fresh water, so there's no salt (the chemical kind) and the fish are therefore more vulnerable.

The comic dialogue itself starts the whole chain of puns off by using the phrase "shooting fish in a barrel", which is figuratively used to mean that the task is extremely easy, but here becomes clear that he is literally executing fish, without needing to be there in person. Also, Black Hat has previously talked about shooting "lonely, angsty fish in a barrel."

It might also be a pun referencing Call of Duty, as the game's acronym is "COD" and Black Hat is seen shooting something on a computer with a "Blam!". In this sense, "remote COD execution" could refer to running Call of Duty on the fish hatchery's computer equipment remotely, though this would then not make this scenario particularly reliant upon anything fish-related, rendering the rest of the puns less explicable.

fish is also the name of a UNIX shell. Shells are popular targets for computer hackers as they are capable of being used to run arbitrary commands if sufficient access is gained through them.

#2959: Beam of Light

July 15, 2024

THE FIRST FEW TIMES EINSTEIN IMAGINED FLYING ALONGSIDE A BEAM OF LIGHT, HE DIDN'T HAVE ANY PARTICULAR INSIGHTS.

Einstein's theories solved a longstanding mystery about Mercury: Why it gets so hot. "It's because," he pointed out, "the sun is right there."

Explanation

Albert Einstein is famous for his theory of special relativity (which deals with the interactions between high speeds and the perceptions of time), and he developed this theory, in part, by imagining himself flying alongside a beam of light. Thought experiments such as this can reveal what appear to be fundamental principles of the universe that can revolutionize scientific understanding.

In this comic, Albert Einstein is depicted having an early version of this thought experiment. At this stage of theory development, it is less about breaking down the complex nature of relativity and more about how fun it would be to go really fast. So his thought experiment is currently just, so to speak, a flight of fantasy. (Although even Einstein's "NYYOOOM" sound of a car whizzing by is the sound of the Doppler effect, which alludes strongly to the relativistic Doppler effect and redshift.) Since this is early in his life, he is most likely sitting in the Swiss patent office he is so famous for working at, when he got his groundbreaking ideas.

In a similar vein, the title text refers to one of the long-standing issues about Mercury: its orbit around the Sun doesn't quite match what Newtonian physics would predict. We now know that this is accounted for by general relativity, another of Einstein's notable theories (which relates how gravity, or the space-time curvature that we understand as gravity, influences time and space, including planetary orbits) that was further developed

out from the framework of special relativity. Again, we find ourselves overhearing his thoughts before he reaches any insights that will start to explain this. Instead he is stuck at just 'imagining' that Mercury is hot due to its proximity to the Sun, which isn't a particularly novel or useful conclusion, or close to what we would now recognize as Einstein's much-lauded theory.

At around the time of the comic's scenario, being only the first stages of Einstein's thoughts about Relativity, the issue of the Sun's heat was still considered a mystery. The Kelvin–Helmholtz mechanism was proposed as the cause of the Sun's heat but was later superseded by the more modern understanding of nuclear fusion. The Yarkovsky effect had also been previously described as how thermal effects may influence orbital dynamics; this is still useful to know about in the case of asteroids but is not considered a significant factor for Mercury. Neither of these things were ever the focus of Einstein's own studies, though in 1915 he showed that General Relativity could explain Mercury's orbital anomalies, and independent observations during a 1919 solar eclipse helped confirm the principles and make Einstein famous.

An older version of Einstein was previously drawn in 1206: Einstein and 1233: Relativity.

Also, a comic with a similar punchline to this one is 2689: Fermat's First Theorem, which has Pierre de Fermat instead of Einstein.

#2960: Organ Meanings

July 17, 2024
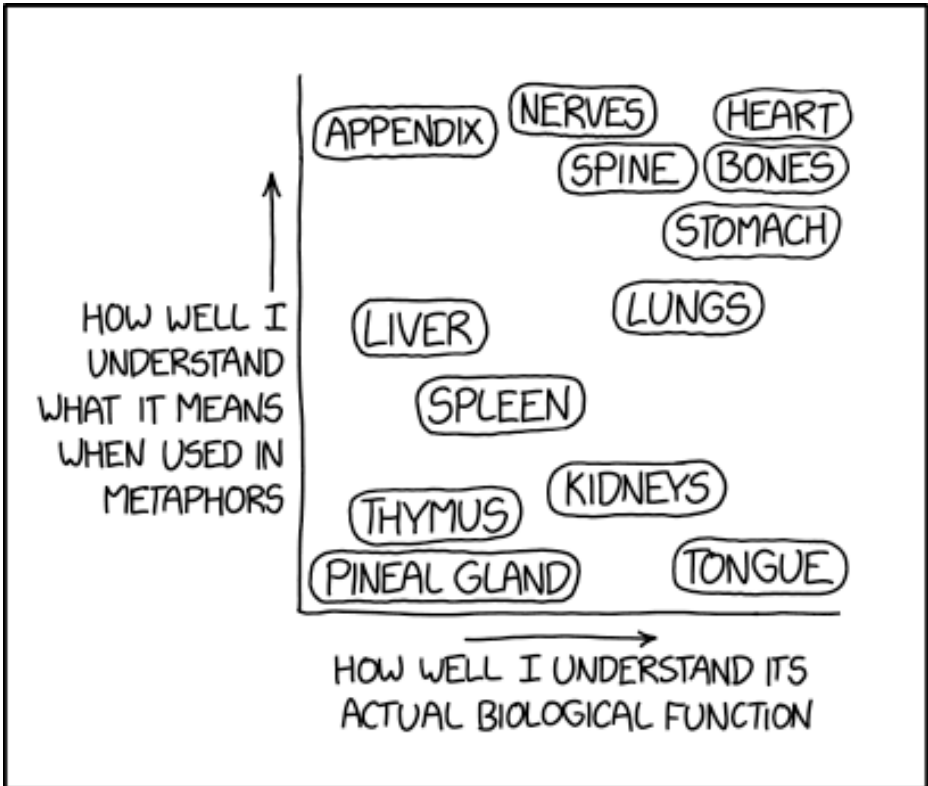
IMO the thymus is one of the coolest organs and we should really use it in metaphors more.

Explanation

This is a graph by Randall ranking how well he understands the function of certain human organs, compared to how much he understands metaphors using them.

A number of organs (and other body parts) are used in common vernacular for metaphorical meaning. The English language is full of sayings like "she had a lot of heart", "go with your gut", and "he hasn't got the stomach for it". One might expect understanding an organ's role and its use in metaphor to be strongly correlated, since the metaphors generally work by drawing a parallel to biological function. However, since our understanding of biological functions has evolved dramatically over time, and metaphorical language does not always keep up, the correspondence is often much looser. To complicate matters, many such anatomical metaphors vary from culture to culture, even though the biological functions remain largely consistent.[citation needed]

The pineal gland, located in the center of the brain, was described as the "Seat of the Soul" by the mind-body dualist René Descartes in the 17th century. If this was true, the metaphors that might be derived from it would be quite clear. It was only in the mid-20th century that its real neuroendocrine (hormone-producing) biological role was grasped. Thus, the real meaning of the metaphor "the pineal gland of something" is uncertain, as is its actual function for the layman. It was also described as a

"third eye", as its regulation of the circadian rhythm used to be linked to light perception in the organ, and still is in Tuataras. It is also jokingly stated as still the location of the soul within discordianism.

The thymus, highlighted in the title text, plays an important role in the immune system. It is not commonly used in metaphors,[citation needed] but is perhaps ripe for use in ones describing such things as resilience, indomitability, and adaptability to changing circumstance, were more people to know what it was.

As Randall does not provide any examples, only his general ratings, it is not entirely clear whether he has restricted himself to metaphors drawing upon the nature of organs (e.g. "heart of the city" or "bone dry") and/or metaphorically describing these organs in terms of another idea ("a heart of gold" or "his bones turned to jelly"). As well as metaphor, the assessment might also involve all closely related (or overlapping) rhetorical devices such as simile ("his heart fluttered like a butterfly"), metonymy ("my mother tongue"), other references with an intent more figurative than literal ("he was a bundle of nerves"), or misattributed bodily functions ("I feel it in my bones"). As such, any contributed examples given here could be disputed in all except the broadest of terms.

#2961: CrowdStrike

July 19, 2024
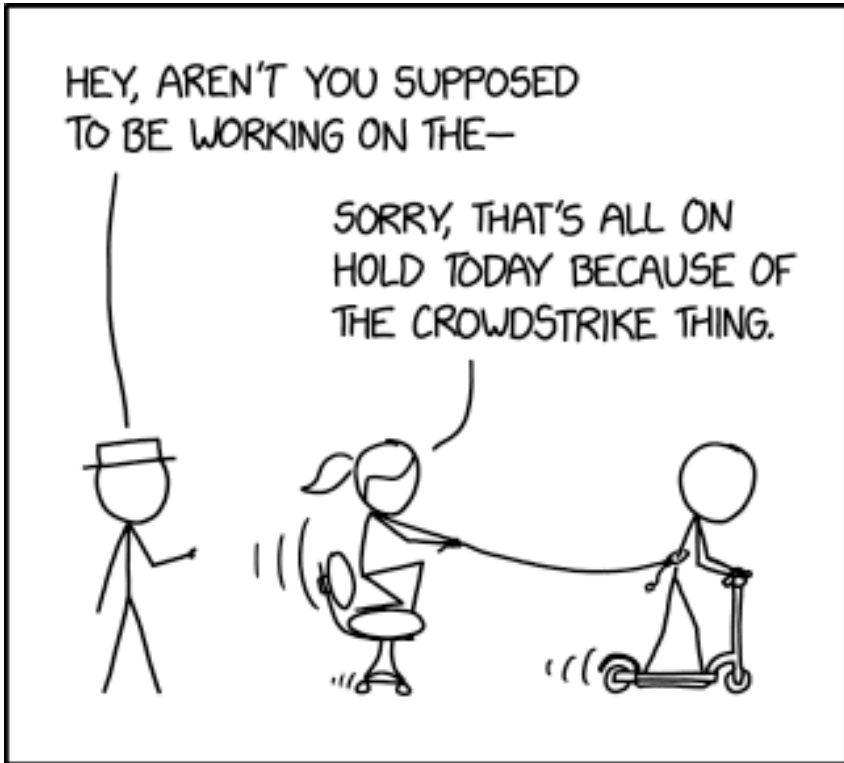
PROTIP: AS LONG AS YOU'RE NOT ACTUALLY IN CHARGE OF *FIXING* THE CROWDSTRIKE THING, YOU CAN USE THIS EXCUSE FOR PRETTY MUCH ANYTHING YOU WANT TO DO TODAY.

We were going to try swordfighting, but all my compiling is on hold.

Explanation

This comic is about the 2024 CrowdStrike-related IT outages occurring on the day of the comic's release. CrowdStrike makes security software to protect computers from malware, ransomware and other cyberattacks. The software is sold to businesses and large enterprises like hospitals, airlines and retailers. CrowdStrike frequently releases updates to their software to handle new types of malware they know about. A faulty update for one of their software products, which was apparently released without adequate testing or quality assurance, caused computers with the software installed to crash (a Blue Screen of Death, given that it caused failures primarily in Microsoft Windows versions 10 and 11) very early on when booting up. This meant the computers could not be quickly or automatically fixed. Because many large businesses with large numbers of computers used CrowdStrike's software on at least some of their systems, or relied upon businesses that did, the resulting disruption was very widespread and very visible, preventing those businesses from operating and, in many cases, preventing their employees from working while their computers were affected. Even nominally unaffected systems (not having CrowdStrike/an afflicted version of Windows installed) could find themselves indirectly, and perhaps only partially, unusable due to relying upon other systems that were afflicted.

Apparently, Cueball and Ponytail's company, or possibly a company providing a service their work depends on,

uses CrowdStrike to secure their computers (although they may just be using it as an excuse to slack off, if their colleagues don't know any better). Without being able to work, they have found something more entertaining to do -- Cueball, riding a scooter and with a rope tied around his waist, is towing Ponytail, who is half-kneeling on a swiveling chair, around their office or neighborhood. Performing this activity is probably a bad idea.[citation needed]

As the caption suggests, not everyone has the luxury of slacking off while their computers are broken. CrowdStrike engineers had to address the faulty update, and help the businesses using their software to fix their computers. And relevant employees at affected customers' IT departments had to work to mitigate the impacts, and to roll out the necessary fixes. In the event, CrowdStrike had released a patch for the software around six hours after it came to light, but this had to be manually applied to each affected device.

The title text refers to 303: Compiling, in which Cueball also found an alternative way to spend time at work when 'forced' to step away from his computer, albeit for a less disruptive reason. But, because of this problem, even the compiling is on hold. If sword fighting is 'officially allowed' only during actual compiling, as that comic implied, then during this instance (forced to be AFK for different reasons) they must resort to yet other activities, such as the one in this comic.

#2962: President Venn Diagram

July 22, 2024
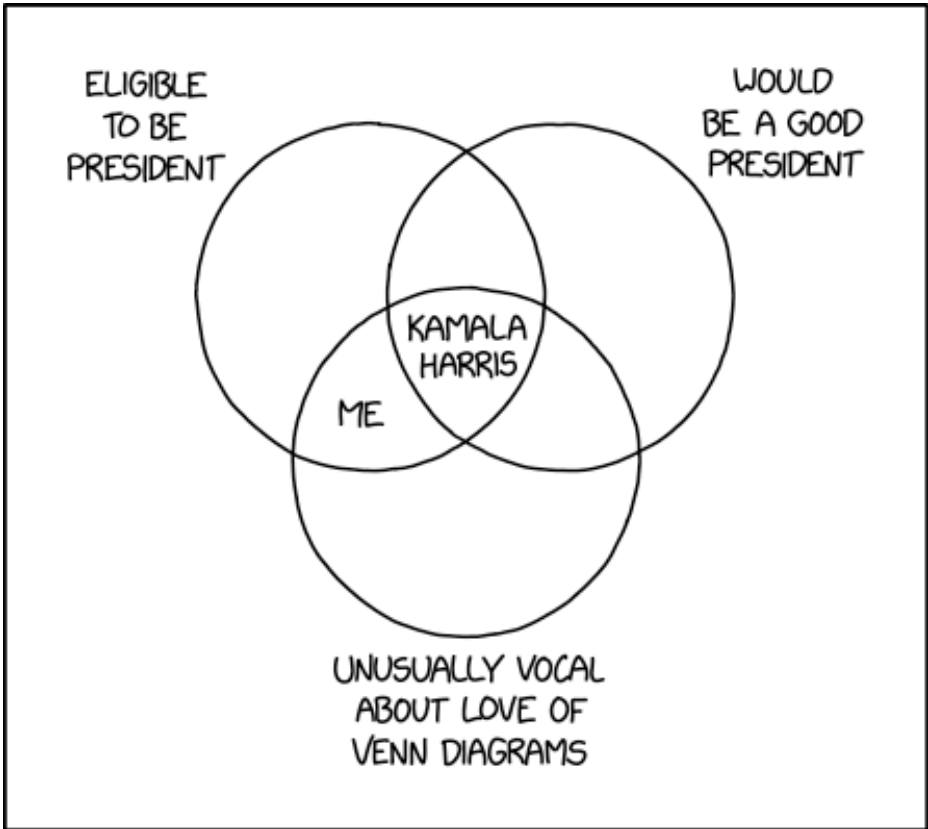
Hard to imagine political rhetoric more microtargeted at me than 'I love Venn diagrams. I really do, I love Venn diagrams. It's just something about those three circles.'

Explanation

On the Monday that this comic was published, US Vice President Kamala Harris became the new presumptive Democratic Party nominee for the 2024 presidential election, having received verbal endorsements from a majority of Democratic state delegations; the day before, President Joe Biden had suspended his re-election bid and endorsed Harris. These major events resulted in Harris replacing Biden as one of the top two candidates for President in the 2024 election, which she eventually lost.

This comic features a three-way Venn diagram (which is also an Euler diagram). The three circles represent eligibility for US presidency, ability to do a good job as the US president, and love for Venn diagrams:

Part of the humor arises from the contrast of putting on a level playing field three characteristics that range widely from the momentous to the quirky, as well as the implication that Randall and Harris are quite similar in all but one area: their fitness to serve as US President, per Randall's opinion. The diagram does not indicate anyone who Randall would include in the six other areas (categories) of the Venn diagram besides the two in which he listed himself and Harris. Randall seems to express support for a Democratic Presidential candidate every 8 years, including in a 2016 comic I'm With Her endorsing Hillary Clinton and in a 2008 blog post endorsing Barack Obama.

The title text quotes Kamala Harris on her affection for Venn diagrams, and implies that the best way to target Randall with political ads is to mention how amazing Venn diagrams are.

#2963: House Inputs and Outputs

July 24, 2024
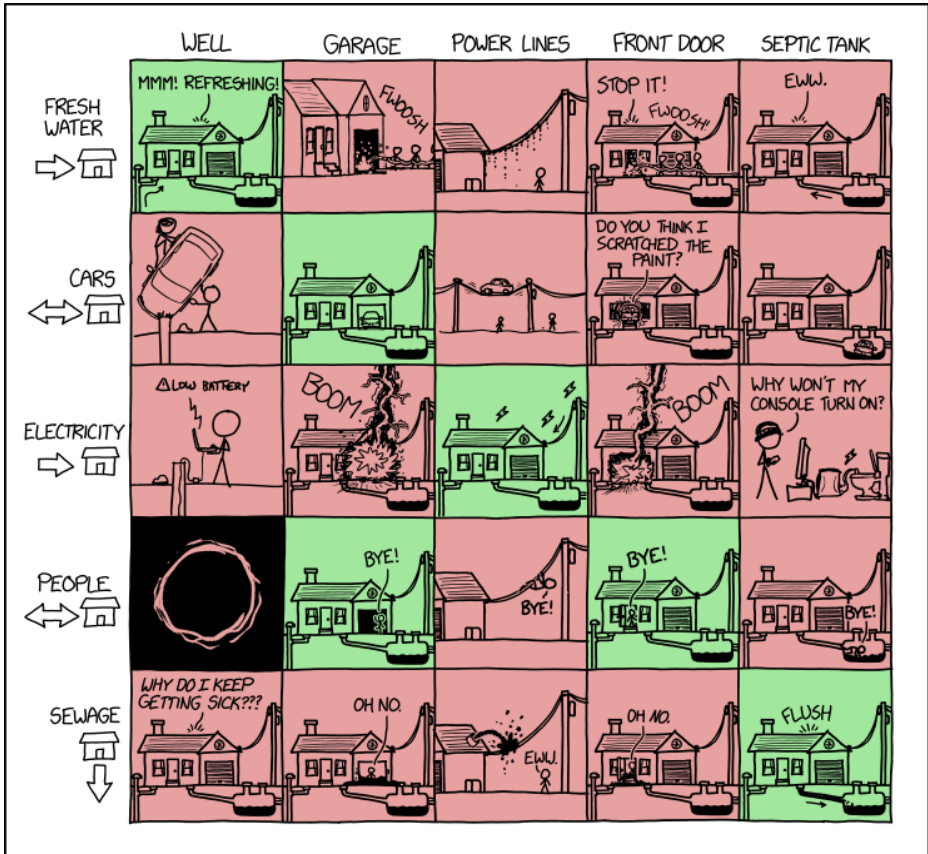
People think power over ethernet is so great, and yet when I try to do water over ethernet everyone yells at me.
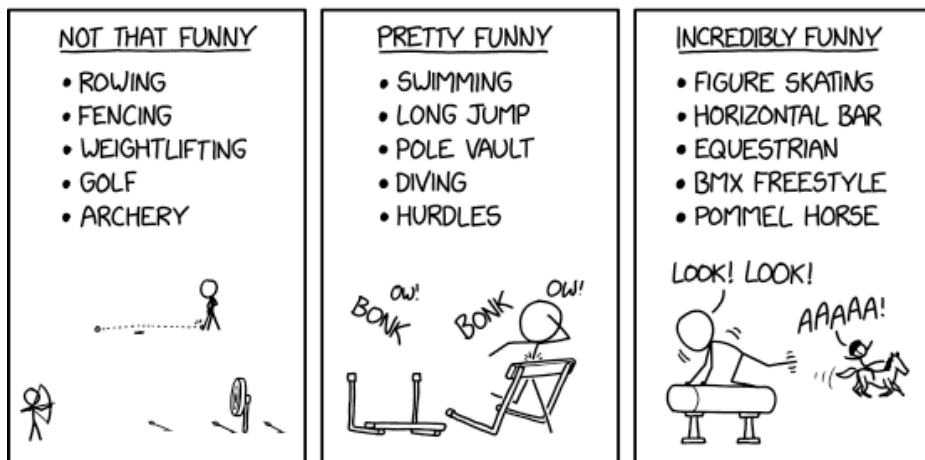
Explanation

This is another comic in a series depicting confusion matrices, similar to 2813: What To Do, 2420: Appliances, and 1890: What to Bring. It is arranged as a table of five columns of conduits to and from a house, by five rows of resources and people, each of which typically enter, exit or both enter and exit the house via at least one of the identified conduits. The table cells have a green background for compatible methods of transit; a red tint is used for the more problematic pairings. Each panel can be read as "[row label] [entering and/or exiting] the house via the [column label]", for example, "Fresh water entering the house via the well".

The title text references power over ethernet (PoE), first implemented in the early 2000s, to provide electric power along with data on twisted-pair Ethernet cabling. A welcome development, it removed the need for many separate power supplies. While networked water delivery ("running water") is also a welcome development, doing so over ethernet cables would be extremely problematic, risking several top points of failure, while providing limited amounts of water. However, again, electric vehicle fast charging cables and arc furnace power inputs are sometimes water-cooled.

#2964: Olympic Sports

July 26, 2024

OLYMPIC SPORTS RANKED BY HOW FUNNY IT WOULD BE IF I, A REGULAR PERSON WITHOUT ATHLETIC TRAINING, SNUCK ONTO THE TEAM TO COMPETE:

NOT THAT FUNNY
- ROWING
- FENCING
- WEIGHTLIFTING
- GOLF
- ARCHERY

PRETTY FUNNY
- SWIMMING
- LONG JUMP
- POLE VAULT
- DIVING
- HURDLES

OW! BONK BONK OW!

INCREDIBLY FUNNY
- FIGURE SKATING
- HORIZONTAL BAR
- EQUESTRIAN
- BMX FREESTYLE
- POMMEL HORSE

LOOK! LOOK! AAAAA!

Thankfully for everyone involved, the Winter Olympics officials spotted me and managed to stop me before I got to the ski jump.

Explanation

This comic was officially published on the day of the opening ceremony of the 2024 Paris (Summer) Olympics, though it actually appeared early the following day.

In this comic, Randall, who has no athletic training, imagines himself participating in various Olympic events, with his degrees of failure measured in terms of their humor potential.

The title text may be a reference to ski jumper Vinko Bogataj, whose spectacular crash at a (non-Olympic) ski flying event in 1970 in Oberstdorf, (then) West Germany became emblematic of the expression "the agony of defeat" in the opening narration of the popular US television program "Wide World of Sports". Alternatively the reference may be to Eddie the Eagle, whose poor performance in the ski jump at the 1988 Winter Olympics led to the introduction of a rule requiring entrants to be ranked internationally in the top 50 and top 30%.

#2965: Chili Tornado Quake

July 29, 2024

A TORNADO THAT STRUCK A CHILI PEPPER PROCESSING PLANT DURING AN EARTHQUAKE WAS RATED 55,000 ON THE RICHTER-FUJITA-SCOVILLE SCALE.

BREAKING NEWS
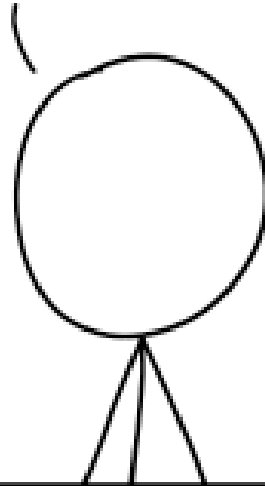
Buildings constructed from softer materials were damaged by chili pepper impacts to the storm's high Richter-Fujita-Scoville-Mohs hardness rating.

Explanation

Cueball, as a news anchor, is reporting on a tornado that struck a chili pepper processing plant during an earthquake, and he rates the event as 55,000 on the (fictional) Richter-Fujita-Scoville scale.

The Richter-Fujita-Scoville scale combines several unrelated scales:

- The Richter scale is a historic (but still well known) logarithmic scale for rating the intensity of earthquakes that typically range from about 3 to 9.5.
- The Fujita scale rates the intensity of damage caused by tornadoes which ranges from 0 to 5.
- The Scoville scale rates the spiciness of food, such as chili peppers, from 0 (not spicy) all the way up into the millions.

The joke is that combining these scales is nonsensical and silly; the effects of each are not interrelated in any meaningful way.

Exactly how the final number of 55,000 was calculated is an exercise for Randall. As mentioned above, only the Scoville scale would normally see numbers this high (for example, an 18 on the Richter scale would vaporize the Earth). Allowing for some speculation, it's likely the three base numbers are multiplied, as with similar compound-unit calculations, to give the single combined measure (although some nominal types are treated as

additive). This would be consistent with likely values of the earthquake, tornado, and chilli peppers:

- Richter: Since the building is still there it is not a 9 on the Richter scale, suggesting a maximum around 8. The fracturing of the earth suggests a minimum of 6.
- Fujita: Given the image, this is not a 5 on the tornado scale, suggesting a maximum around 4. The severe damage to the building suggests a minimum of 3.
- Scoville: This would then leave the rest for the Scoville scale. 55,000 divided by estimates of 8 and 3 would give around 1700 Scoville units, a normal value for poblano peppers (Scoville number between about 1000 and 2000). The other two numbers could also be smaller, requiring a higher Scoville rating to reach 55,000 through multiplication, but there are many hotter peppers to make up the difference, such as jalapeño peppers (2500 to 10,000 Scoville units) among others.

In the title text it is mentioned that buildings constructed from softer materials were damaged by chili pepper impacts [due] to the storm's high Richter-Fujita-Scoville-Mohs hardness rating. The Mohs scale is a scale for mineral hardness which ranges from 1 (e.g. talc) to 10 (diamond), with lower numbers being softer and higher numbers being harder. Chili peppers are strong in a spicy sense, but very soft on the Mohs scale, so if it was only the chilies that hit other buildings it would only be very soft material that would take any damage. Of course there would also be building material hitting nearby houses, thus they would do more damage

than the chili, by an amount that would depend upon the relative hardness of the processing plant structure to that of other buildings. The former is frangible enough to have become dislodged from its structure, but may be just as brittle as it is ultimately abrasive, or is composed of thoroughly resilient pieces of material previously held in place by mortar or some other binding of insufficient adhesion or mechanical strength. From either point or failure (or both!), the wind-whipped cloud of debris might then indeed be able to scour more generally well-built structures nearby, even ones actually designed to withstand and absorb such winds/earth movements in their own right.

A number, where the hardness of the materials hitting nearby buildings was taken into consideration, could have been given, adding a fourth number to consider in the scale, but no such number is provided.

Similar comics:

- 2950: Situation - several unlikely scenarios, all at once
- 1531: The BDLPSWDKS Effect - also a hybrid multi-disciplinary amalgam of measurements
- 1794: Fire - featuring a multiple-alarm fire in an alarm factory

Discussion: Is the title text missing a word?[edit]

The title text might be missing the word "due," or it might not be a typo; both scenarios are possible, but the meaning changes.

Since it's impossible to say which scenario is correct, here are the

implications of both.

The sentence as written means that the chili peppers impacted the magnitude of the scale. In other words, buildings made of soft materials were damaged because the Richter-Fujita-Scoville-Mohs hardness rating was higher than it otherwise would have been as a result of the chili peppers. This suggests that spicier peppers are more likely to damage soft buildings.

The text has a somewhat awkward and unusual phrasing, if this was the intended meaning. If it was intended, Randall is presumably making a pun on the word impact, using it in an unusual way. Discussion about impacts from disasters usually talk about physical impacts, not impacts to abstract measurement systems, so the joke may be about this secondary kind of impact.

"Buildings constructed from softer materials were damaged by chili pepper impacts due to the storm's high Richter-Fujita-Scoville-Mohs hardness rating."

The sentence with "due" means that soft buildings were damaged by chili peppers, since the storm's hardness rating was high enough. This seems more straightforward: harder peppers successfully effacing soft building materials.

#2966: Exam Numbers

July 31, 2024

KINDERGARTEN MATH FINAL EXAM

Q. WRITE DOWN THE BIGGEST NUMBER YOU CAN THINK OF

A. [ ]

PRE-ALGEBRA FINAL EXAM

Q. WRITE DOWN THE VALUE OF x IF x=3x−8

A. [ ]

CALCULUS FINAL EXAM

Q. WRITE DOWN THE VALUE OF $\int_0^\pi x \sin^2 x \, dx$

A. [ ]

PhD COSMOLOGY FINAL EXAM

Q. WRITE DOWN THE HUBBLE CONSTANT TO WITHIN 1%

A. [ ]

GAME THEORY FINAL EXAM

Q. WRITE DOWN 10 MORE THAN THE AVERAGE OF THE CLASS'S ANSWERS

A. [ ]

POSTGRADUATE MATH FINAL EXAM

Q. WRITE DOWN THE BIGGEST NUMBER YOU CAN THINK OF

A. [ ]

Calligraphy exam: Write down the number **37**, spelled out, nicely.

Explanation

The comic depicts various similarly formatted examination questions that might appear on test papers at various points in a student's potential academic career. While they all share a similar feel, they are asking for different things, some of which might be considered more serious and examinable proofs of study than others. The joke is that the first and last questions are the same, but have very different interpretations based on the context.

Note that "PhD Cosmology" and "Postgraduate Math", unlike the other items, aren't specific courses but instead refer to areas of study, and as such wouldn't have a exam (unless a PhD thesis defense is considered an "exam").

This style of final exam question, un-numbered and therefore possibly the only question upon the whole of each final paper, in some ways (for some instances) echoes the question "What is your name?" that Randall will be aware was the sole question given to Discworld's Victor Tugelbend in an attempt to ensure he comprehensively passed (or utterly failed) his final student-wizard's exam, after many prior times of deliberately not-quite-passing.

#2967: Matter

August 02, 2024

IN THE STANDARD MODEL, REGULAR MATTER WILL ANNIHILATE IF IT COMES IN CONTACT WITH OPPOSITELY-CHARGED GOOFY MATTER.
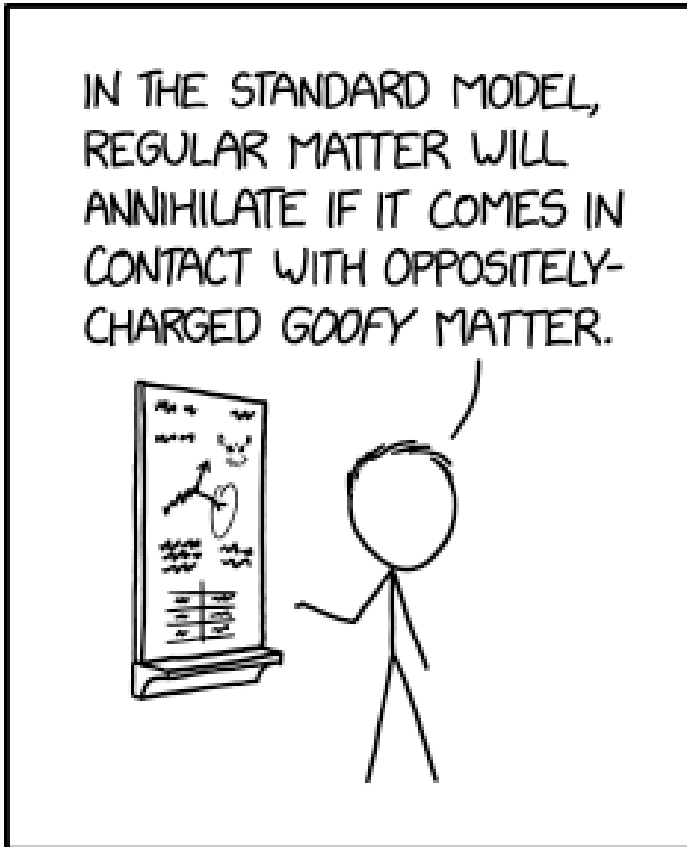
TONY HAWK BECOMES A PHYSICS PROFESSOR

He was the first person to land a 900, which is especially impressive because pulling off a half-integer spin requires obeying Fermi-Dirac statistics.

Explanation

In skateboarding, the term "goofy" refers to a skater using the goofy stance, with the skater's right foot at the front of the board and left foot at the rear. This is backwards from how most right-handed people feel most natural when stepping on a skateboard. In this comic, famed professional skateboarder Tony Hawk, who skates goofy-footed, has obtained a professorship in physics and is teaching about antimatter in particle physics, which has the opposite electrical charge of corresponding matter particles that will annihilate each other upon collision, releasing energy proportional to their combined mass. As Tony Hawk does not have a degree in physics,[citation needed] teaching inaccurate or very non-standard lessons such as this one could be a likely pitfall of his gaining a professorship in real life. Hawk is also the subject of 296: Tony Hawk.

Unlike other distributions of 'handedness' in the natural world (chemical chirality, or the skewness of bimodal statistics describing asymmetries in nature called homochirality), 'goofy-footed' skateboarders are about as common as those using standard footing. Thus the analogy indirectly raises the issue of baryon asymmetry, the observation that ordinary matter is very much more common than antimatter because there is so little evidence of annihilation throughout the universe. Baryon asymmetry is often thought to have resulted from fluctuations during cosmological inflation between $10-33$ and $10-32$ seconds after the Big Bang, although

there are several other candidate explanations of varying falsifiability.

The title text describes Hawk as the first person to "land a 900," meaning the successful completion of a skateboarding trick that involves two and a half rotations (nine hundred degrees, as 2.5 × 360° = 900°). In physics, spin is a quantum number describing subatomic particles (see 1862: Particle Properties), named in reference to the vaguely analogous but crucially distinct concept of angular momentum in classical physics. Obeying Fermi–Dirac statistics requires that the particles involved are fermions, which include all of the electrons, protons and neutrons that compose the entirety of everyone's body and electrochemical state. Fermions all have half-integer (i.e., ...−1½, −½, ½, 1½...) spin quantum numbers which do indeed include 2½, but only extremely rare particles have a spin of 5/2. However, it's very important to remember that quantum mechanical spin is not rotation, but instead how quickly the corresponding particle changes state when rotated.

While everyone (and almost everything we ordinarily interact with except light and cosmic rays) is composed entirely of fermions, any composite particle made of an even number of fermions, including entire atoms and their nuclei, are not fermions but bosons, which do not obey Fermi–Dirac statistics. Luckily, landing a 900 does not actually require obedience to Fermi–Dirac statistics because a skateboarder composed entirely of bosonic atoms would still have fermionic electrons in the orbitals of those atoms and thus would still obey the far more

macroscopically fundamental and consequential Pauli exclusion principle. That principle gives atoms and molecules, which are almost entirely empty space, tangible presence and material form, allowing us to hold things, walk, make sound waves with our voices, employ any mechanical property of matter, and allowing sufficiently skilled skateboarders to land a 900.

August 05, 2024

WHEN I TOOK THE HELM FIVE YEARS AGO, OUR UNIVERSITY WAS 213 YEARS OLD—THE SECOND OLDEST IN THE STATE, JUST BEHIND OUR 215 YEAR OLD RIVAL.

UNDER MY LEADERSHIP, WE'VE FUNDED AN INTENSIVE PROGRAM TO INCREASE OUR AGE TO 218, OVERTAKING OUR RIVAL BY 3.

UNFORTUNATELY, I HAVE TERRIBLE NEWS.
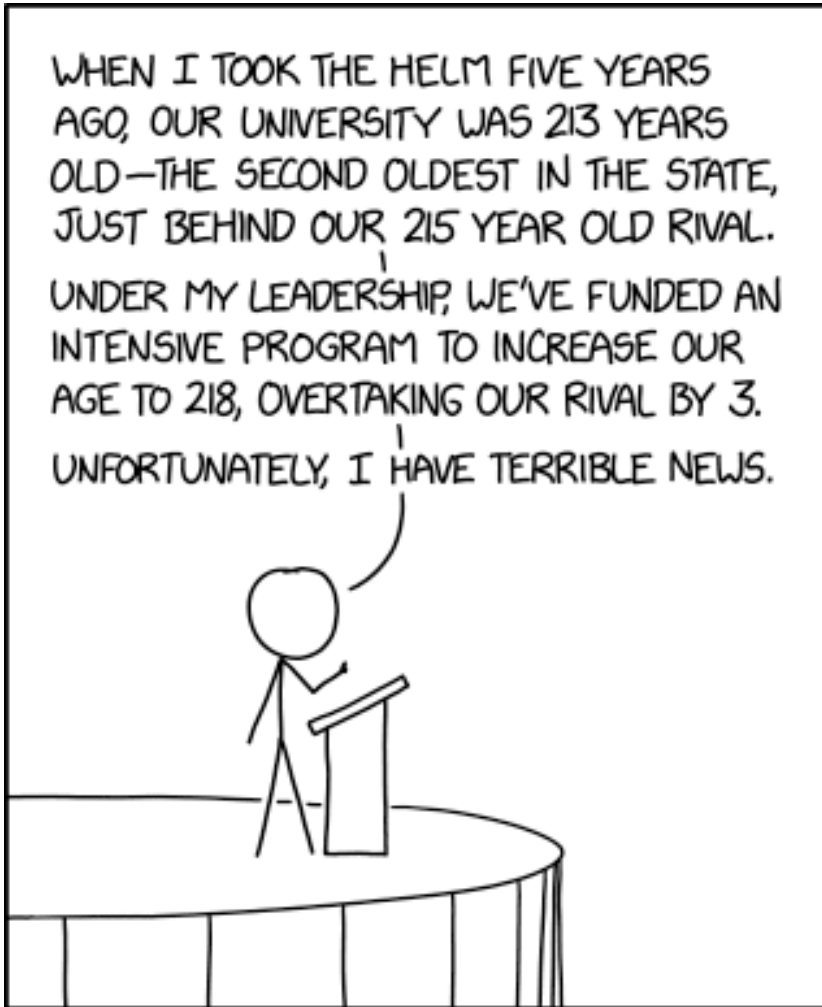
This only makes it more urgent that we adopt my roadmap for the next 10 years, which should put us solidly in the lead.

Explanation

Cueball has been the leader of a university for the last five years. In a speech, he declares that his goal during those five years has been to make his university overtake the age of the oldest university in his state, which is obviously impossible.[citation needed] The other university was then two years older than his own (215 years vs 213 years old). He states he has funded an intensive program to make the university five years older, or three years older than the rival university was. That would have happened anyway, whatever he had done (short of such gross mismanagement as to cause his university to cease operations), or if he'd done nothing at all.

The final line of Cueball's speech, "Unfortunately, I have terrible news", presumably precedes the announcement that the rival university has also aged 5 years and is therefore just as far ahead as they were before.

Universities often plan ambitious initiatives to boost prestige. However, true success often depends on factors outside administrative control, such as student quality, alumni achievements, faculty research, historical reputation, and external economic and social factors. While administrative efforts are important for operations and gradual improvements, a university's overall prestige cannot be engineered quickly through planning alone.

In the title text, Cueball's proposed "roadmap for the next 10 years" could mean more of the same ineffective

efforts, perhaps merging his university into another institution that was founded before the rival university, or undermining the rival university so it ceases operation, probably by malicious means. A much more unlikely plan could involve placing the rival university in a spacecraft on a near-light speed journey, slowing its apparent age due to relativistic time dilation. Most likely, his plan is to continue doing the same thing as he'd done the last five years but making it sound like a new idea even though nothing will ultimately change. This may be part of the joke.

#2969: Vice President First Names

August 07, 2024

	PRESIDENT	VP
2024	? KAMALA / DONALD ?	TIM ? / JD ?
2020	JOE	KAMALA
2016	DONALD	MIKE
2008	BARACK	JOE
2000	GEORGE	DICK
1992	BILL	AL
1988	GEORGE	DAN
1980	RONALD	GEORGE
1976	JIMMY	WALTER
1974	GERALD	NELSON
1973	RICHARD	GERALD
1968	RICHARD	SPIRO
1964	LYNDON	HUBERT
1960	JOHN	LYNDON
1952	DWIGHT	RICHARD

☐ FOUR LETTERS OR FEWER

SINCE THE 1980s, A POLITICAL CONSENSUS HAS EMERGED: VICE PRESIDENTS SHOULD HAVE SHORT FIRST NAMES.

[Political pundit on the ScrabbleTV News channel] "After four years of defying orthographic pressure, Joe ceded the top of the ticket to Kamala, who--after considering Josh, Mark, Andy, Roy, and Pete--picked Tim."

Explanation

Randall observes that American Vice Presidents since the 1980s have almost all gone by short first names. It should be noted that all of the "short" first names in this strip, with the exception of John (F. Kennedy) are diminutives (or initials) of longer names, but all represent the names which the candidates preferred and publicly used. This comic was published one day after Kamala Harris (who replaced Biden as presidential candidate) chose Tim Walz as her running mate for the 2024 presidential election. Both the Republican and Democratic tickets are listed for 2024, since the 2024 election had not yet concluded when this comic was made. Either party winning would match the observation.

In the comic's caption, Randall amusingly describes this as an emerging "political consensus."

While not a "political" consensus per se, the observed phenomenon is a type of consensus — reflecting a multi-decade change in US societal norms — and is not simply a random coincidence.

• There has been a national US trend toward shorter names since the 1980s and 1990s, with a rise in the popularity of baby names like Ryan, Kyle, Amy and Lisa. (The trend has continued, with even shorter names like Ava, Mia and Max becoming more common in the 2000s and 2010s.)
• This has paralleled a trend in shorter business names,

with companies like Dell, Cisco and eBay before the turn of the millennium and Google, Uber and Lyft after (cf. pre-1980 businesses like AT&T, BNSF or 3M which had to convert their very long names into acronyms to adapt). Product naming also began to simplify in the late 20th century, driven by marketing strategies that favored brevity and memorability, exemplified by Apple's iconic "iMac" and "iPhone" products.

- All of these naming trends reflect a general societal trend toward minimalism and less formality, also seen with corporate logos, product design (Apple), clothing design (Gap), furniture design (IKEA) and web/app design.

This societal shift may explain why many politicians with given names like Albert and Richard might have preferred to go by shorter, less formal sounding, more approachable names like Al and Dick, to match the zeitgeist.

That Vice Presidents have used shorter names than Presidents since the 1980s is an interesting coincidence (more discussion below). Most of the Presidents since the 1980s happened to have names (such as George, Barack and Kamala) that can't be easily shortened. And the exception, Donald Trump (which can be shortened to Don), did not become a politician until the nice age of 69, when he was already nationally famous using his full name.

The title text amusingly suggests (1) the existence of a

ScrabbleTV News channel (named after the word game) staffed with (2) political pundits who (3) report Biden's decision to end his re-election campaign as being driven by orthographic (related to the writing of words) pressure to conform to the aforementioned political consensus. Having Joe Biden as President and Kamala Harris as VP violated this pattern, but elevating Harris to the presidency and selecting a short-named running mate restored it. Like Tim Walz, all of the final six candidates considered as Harris's running mate had short first names: Josh Shapiro, Mark Kelly, Andy Beshear, Roy Cooper and Pete Buttigieg.

- This could also be a subtle joke about political pundits tending to give confident, inaccurate hot-takes. (Biden's decision was driven, among other things, by worsening polling, rising concerns about his age, a poor debate performance against Trump and subsequent pressure from other leading Democrats.)

This is Randall's second recent comic about US politics and Kamala Harris, the first being 2962: President Venn Diagram which was published right after she rose to the top of the Democratic ticket.

Observations[edit]

It is interesting that, even ignoring the stricter definition of having less than four letters in their name, only four pairings have a Presidential given (or adopted) name that is shorter than the Vice-Presidential one, and just two further cases (one of these not involved in winning an election) have equal length names.

Contextual table of names[edit]

#2970: Meteor Shower PSA

August 09, 2024
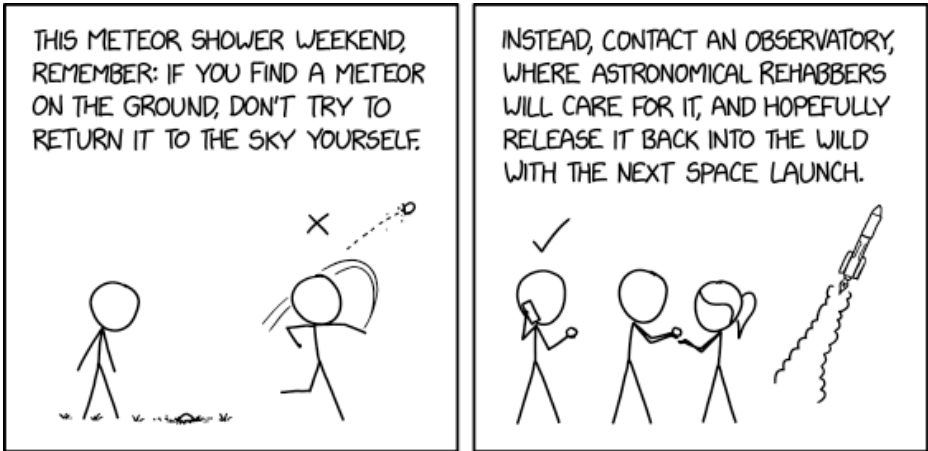
If you hold the meteor too long, it may imprint on you and form a contact binary, making reintroduction to space difficult.

Explanation

This comic is a public service announcement (PSA) regarding what to do in case you discover a meteorite from the upcoming Perseid meteor shower, which occurred the weekend after this comic appeared. (See here regarding 1723: Meteorite Identification).

In the first panel of the comic, Cueball finds a meteorite on the ground, likely from the Perseids meteor shower. He then tries to throw it back into space, which is obviously impossible. However, the comic marks this action as wrong (with an X) not because it's impossible, but for a different reason. The PSA in the next panel (marked as correct with a check mark) suggests that instead of throwing it, Cueball should contact an observatory and deliver the meteorite to them. There, astronomers like Ponytail can care for it, possibly releasing it back into space during the next launch.

This idea mixes up the concept of meteoroids with baby animals that have been separated from their parents and need rehabilitation—like baby birds that have fallen from their nests (though usually from trees rather than the sky). The advice for finding a wild animal, especially a baby one, is generally to leave it alone because its parents are likely nearby and taking care of it. If the animal is sick, injured, or orphaned, it's best to contact a wildlife rehabilitator who can properly care for it and return it to the wild. However, this advice does not apply to meteors.[citation needed]

If you find a recently fallen meteorite or a fragment of one, avoid touching it, as it may be extremely cold. Though the meteor's surface is heated by the atmosphere during its descent, the interior remains as cold as space, and the surface will rapidly cool if it hasn't already. The coldness depends on the meteorite's size, fragmentation, and how long it has been on the ground—unless it was large enough to generate additional heat from the impact. Experts prefer you not handle meteorites directly, as this can contaminate the specimen, making it less valuable for scientific study. In rare cases, such as with more dangerous examples, the meteorite could even contaminate you!

Technically, Randall uses the term "meteor" incorrectly. A "meteor" refers to the streak of light seen when a meteoroid enters the atmosphere. If a piece survives and lands on the ground, it's called a "meteorite" (although some refer to it as magma). This might be intentional to fit the "lost baby bird" analogy, as, like baby birds (except for those from ground-nesting species), a true meteor should never be found on the ground.

The title text humorously suggests that handling the meteor for too long might result in forming a contact binary, which is when two space rocks stick together. While this term is also used for binary star systems, it's unlikely that a person and a rock would form one.[citation needed] In rehabilitating young animals, preventing imprinting—where the animal forms a psychological attachment to its caregiver—is important because the animal needs to be able to survive in the wild

without human help.

#2971: Celestial Event

August 12, 2024

APPROXIMATE FREQUENCY IN MY AREA

ACTIVE NORTHERN LIGHTS: 20 DAYS PER SOLAR CYCLE

A NAKED-EYE "GREAT COMET": 2 MONTHS EVERY 50 YEARS

TOTAL ECLIPSE: ONCE EVERY 350 YEARS

CLEAR SKIES: 50% OF THE TIME

17-YEAR CICADA EMERGENCE: 2 MONTHS EVERY 17 YEARS

$$\left(\frac{20\ DAYS}{11\ YEARS} \times \frac{2\ MONTHS}{50\ YEARS} \times \frac{1}{350\ YEARS} \times \frac{1}{2} \times \frac{2\ MONTHS}{17\ YEARS} \right)^{-1} = 4.3\ BILLION\ YEARS$$

EVERY 4 BILLION YEARS OR SO, MY NEIGHBORHOOD
GETS TO SEE A *REALLY* SPECTACULAR SHOW.

If we can get a brood of 13-year cicadas going, we might have a chance at making this happen before the oceans evaporate under the expanding sun.

Explanation

This comic highlights the extreme rarity of witnessing multiple special events—auroras, great comets, total solar eclipses, and 17-year cicada emergences—all occurring simultaneously in the same location. It calculates that such an event would happen only once every 4.3 billion years, a time span comparable to the age of the Earth. The comic was posted shortly after some people reported seeing auroras in conjunction with the Perseids meteor shower. Randall also includes a 50% chance of clear skies, which further reduces the odds of witnessing all events together. The comic exaggerates the difficulty of this happening, emphasizing that these conditions align less often than Earth's lifespan, suggesting such a celestial spectacle might only occur once before Earth becomes uninhabitable.

The calculation assumes that these events occur independently and that their probabilities remain constant over time, leading to the improbable result. However, this is a simplification, as factors like orbital mechanics and atmospheric conditions are not entirely random, whereas others, such as the amount of cloud cover and the existence of cicadas, may change unpredictably over time. Randall estimates that total solar eclipses occur once every 350 years at a given location, a value close to the 320 year interval for his hometown of Boston, Massachusetts, based on NASA's computations. Another problem is that the lunar orbit is slowly expanding, and thus total solar eclipses will cease

to be possible at some point in the future.

The title text humorously suggests using 13-year cicadas instead of 17-year ones to improve the odds, reducing the interval to 3.29 billion years. This idea, along with the possibility of weather manipulation, reflects Randall's satirical take on humanity's desire to control or predict natural phenomena, even when the timescales involved are beyond human comprehension. Earth's oceans may evaporate in about a billion years , adding a layer of urgency and humor to the idea of witnessing this "super-event" before life on Earth ceases to exist.

#2972: Helium Synthesis

August 14, 2024
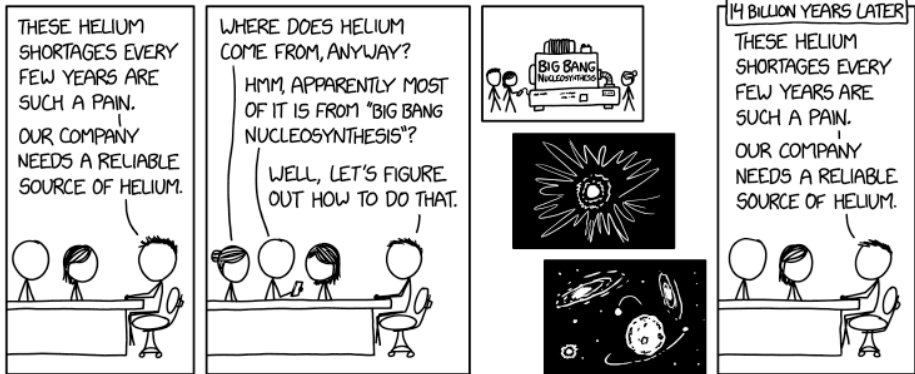
Our lawyers were worried because it turns out the company inherits its debt from the parent universe, but luckily cosmic inflation reduced it to nearly zero.

Explanation

This comic explores the challenges of obtaining helium. Hairy is leading a company meeting with Megan, Cueball, and Hairbun, who are discussing the recurring problem of helium shortages, a real-world issue due to helium's limited availability on Earth. Helium is, for practical purposes, a non-renewable resource primarily extracted from natural gas deposits and its scarcity can affect industries such as medical imaging, semiconductor manufacturing, scientific research, and party balloon supplies. See also 2766: Helium Reserve. In theory, it is a renewable resource, in that a nearly unlimited amount could be produced by nuclear fusion or harvested from the sun. However, the technology to do so has not been invented.

Hairbun suggests investigating the origin of helium. Cueball's research reveals that most helium in the universe came from Big Bang nucleosynthesis, which occurred shortly after the Big Bang when the first elements were formed. It appears to have overlooked the fact that 99% of the helium on Earth has been produced from the slow radioactive decay of the decay chains of naturally occurring uranium-238 and thorium-232 (which in turn came from r-process nucleosynthesis scattered from merging neutron stars; see 2826: Gold) emitting alpha particles that are identical to temporarily ionized helium, with only the remaining one percent originating from the Big Bang.

Hairy assigns the team to figure out how to recreate Big Bang nucleosynthesis, which in real life is not actually possible for a contemporary business organization.[citation needed] Nonetheless, the team somehow builds a machine capable of it. They are successful, likely obliterating themselves and at least all the closest galaxies in the process. Alternatively, they may have created a separate universe containing the subsequent events, thus simply removing themselves from the scope of the comic.

The final panels show the creation of a second Big Bang followed by the next 14 billion years of that new universe, culminating with the same characters in an identical meeting, presumably having arisen from the same series of post-Big Bang events as in the original universe. This suggests a cyclic universe in which events repeat themselves exactly (which chaos theory implies would be extremely unlikely.[actual citation needed]) They are facing the same predicament: helium shortages have become a problem, and they once again need a more reliable source. The implication is that this is a recurring cycle, a religious/philosophical concept called eternal return that occurs in many world religions (such as Hinduism's Cycle of Yugas of creation and destruction), but centered here on the helium needs of a unnamed, resourceful company.

Another possible interpretation is that the new Big Bang does not destroy the existing universe, but creates a new one connected in some way to the old, from which helium can be extracted. This new universe's inhabitants

would eventually develop the same problem with a shortage of helium, causing them to create another new universe to get helium from it, ad infinitum.

The title text is a wordplay on the concepts of cosmic inflation and monetary inflation. In economics, monetary inflation is the rate at which the cost of goods and services increases over time (one can also think of this as the value of money falling). If the interest rate on a debt is less than inflation, then the relative cost of the debt decreases over time. Cosmic inflation is a theory in cosmology that describes the rapid expansion of the universe just after the Big Bang. The joke imagines the original company as having incurred a significant debt (perhaps as a result of the costs of building the Big Bang machine), which has now been inherited by its subsidiary. Somehow, thanks to the effect of cosmic inflation, this debt was diluted (perhaps physically across the ever-expanding vastness of space), reducing it to almost nothing. See also 2688: Bubble Universes.

#2973: Ferris Wheels

August 16, 2024
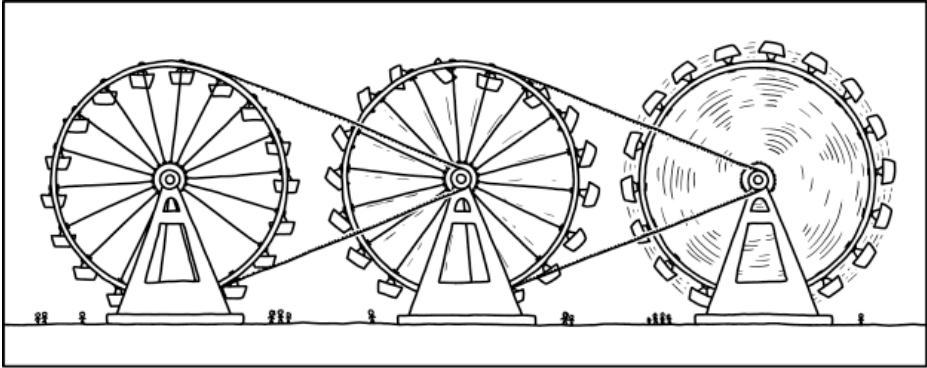
THE COUNTY FAIR FIRED ME FOR ADDING A BELT DRIVE TO THE FERRIS WHEELS.

They left the belt drive in place but switched which wheel was powered, so people could choose between a regular ride, a long ride, and a REALLY long ride.

Explanation

This comic depicts an attempted connection of three Ferris wheels using a mechanical belt drive, a system used to transfer motion between rotating shafts such as what these become. By connecting the belt to different circumferences, the relative motion is geared up or down. If the belt passes around the circumference of one wheel and is connected around the hub of another, the latter will rotate significantly faster. In this case, the second wheel's circumference is in turn connected to a third wheel's hub, resulting in even greater rotational velocity. However, this setup is mechanically unsound and possibly dangerous,[citation needed] as Ferris wheels are not intended to be connected in this way. As shown, the first wheel on the left is running at a normal speed, while the other two are rotating increasingly fast, leading to a potentially hazardous situation where passengers are flung around to various extents.

Ferris wheels can vary widely in size and speed of rotation, but for illustration, let us assume a diameter of about 200 feet (60 m) and a pretty sedate speed of around 10 minutes per full rotation. The apparent ratio between the connected wheels in the comic is approximately 12.5:1, meaning the motion is significantly sped up as it's transferred. The second Ferris wheel, driven by the first, could spin at around 1.3 rpm, with passengers moving at 9 mph (14 km/h), giving a more exciting ride, but not inherently dangerous. However, when this motion is further transferred to the

third Ferris wheel, it could spin at a possible 16 rpm, with passengers traveling at over 110 mph (180 km/h), subjecting them to around 8 Gs of force. Randall has previously explored the limits of the human body's tolerance for acceleration in What If # 116 "No Rules NASCAR". Additionally, if a Ferris wheel span at 110 mph (180 km/h) it would itself be just as dangerous even without any riders. However, since the motor for the first wheel would have been selected merely to drive one wheel, it's unlikely it would be able to power the other two wheels moving at these increased speeds — if it moved at all, all three would probably start to move quite slowly, with potential damage to the motor before any friction limitations and other mechanical failures kicked in.

In the caption Randall says that he was fired for this ill-advised modification, highlighting the impracticality and dangers of the idea. A cruise line also fired the respective narrator due to an unsound engineering proposal earlier in 2935: Ocean Loop.

The title text imagines the consequences of leaving the belt drive system in place but switching which wheel is powered. If the most extreme wheel (the third one on the right) is powered, the gearing would be reversed, making for a possibly pleasant and normal ride on the right-hand wheel, but rendering the experiences of the riders on the other two wheels far too slow for an enjoyable carnival ride. One revolution of the center wheel might take two hours and five minutes, while the left wheel would take around a little more than a day per revolution.   This

exaggerates the impracticality and unintended effects of using a belt drive system to link up Ferris wheels, illustrating how such an idea would lead to absurdly varied ride experiences.

#2974: Storage Tanks

August 19, 2024
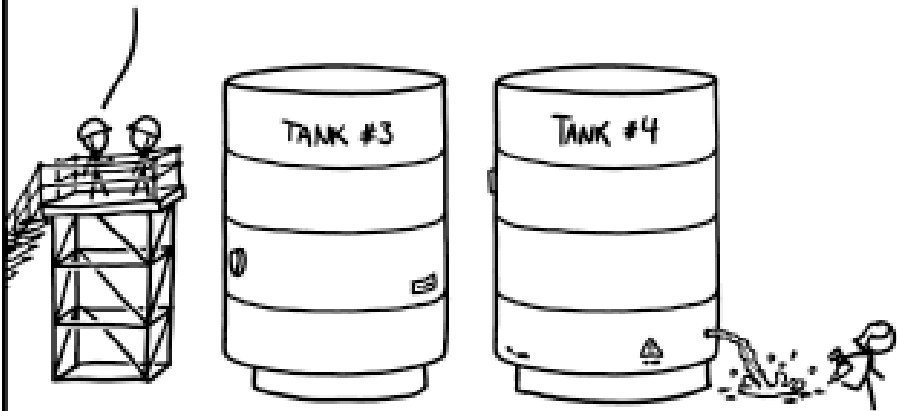
We're considering installing a pressurization system to keep the tanks at constant pressure solely to deter them.

Explanation

Calculus is a branch of mathematics which deals with continuously changing values. In order to demonstrate the application of this sort of math, introductory courses will commonly use physical examples to show how equations can be applied in real life. A common example of such a problem is to postulate a tank full of liquid, with a hole near the bottom, and ask the students to calculate how long it will take the tank to empty (generally assuming a cylindrical tank with the top at atmospheric pressure, leaking a low-viscosity fluid like water at a normal temperature flowing through a round hole.) The important variables are threefold: the radius of the tank, the height of the fluid above the hole, and the size of the hole.

In this case, the change in the liquid level is a function of the rate of flow through the hole, which is a function of the fluid pressure at the entrance to the hole (in accordance with Torricelli's law), and that pressure is a function of the remaining level of liquid. Accordingly, the amount of fluid left in the tank above the hole will follow a quadratic decay, a concept covered in calculus courses. A student with a mastery of foundational principles of calculus should be able to calculate the decline in tank level. More advanced versions of the problem might involve (A) one tank draining into a second, which drains to the ground, or (B) a sealed tank, in which air pressure at the top falls as the tank drains.

As mentioned, many STEM teachers like to use real-world examples, ideally physical demonstrations, to make abstract concepts more memorable for their students. A teacher might fill a jug with water, open a hole in the side, and invite students to compare the observed rate of draining to their calculations. This comic suggests that Miss Lenhart has taken this idea to extremes, having entered an industrial site and drilled a hole into a large, liquid-filled vat. One assumes that her class is either watching from afar, or that the leak is being somehow filmed.

The conversation between the employees in hardhats implies that there's a rash of calculus teachers conducting similar demonstrations, to the point that the primary job of the head of security is to prevent this pedagogically-motivated destruction. In real life, this vandalism would be serious, with safety risks from damaged vats, pressurized liquid, or hazardous contents (note the hazard warning () on the tank).

The title text jokingly alludes to the fact that by maintaining a constant pressure at the level of the leak, the rate of flow would also become constant, and the decline in level would therefore become linear, greatly simplifying the problem and eliminating the need for calculus. This easier version of the problem would presumably deter calculus teachers from using it as a demonstration — though it might attract similarly adventurous algebra teachers.

Analysis and Calculation[edit]

Observation of the comic suggests the following assumptions:

- Tank height above hole: ~20 feet
- Tank radius: ~6 feet
- Type of drill bit: Normal twist drill bit (not a hole saw)
- Size of drill bit: 1 inch (largest commonly available twist drill bit)
- Goal of Miss Lenhart: To demonstrate quadratic decay to her students

With a tank that is 20 feet high, has a 6-foot radius, and a 1-inch diameter drill hole, it would take approximately 21.5 hours for the tank to empty completely — too long for a suitable class demonstration — though maybe filmed as a time-lapse video? — and nonetheless likely to be fixed by nearby workers who notice the leak.

To drain the tank in 36 minutes would take a 6-inch diameter hole.

Thus there's an apparent mismatch between the drill bit size, gushing liquid stream, and practicality of this real-world demonstration. The viscosity & density of the liquid is also an unknown factor; for ease of calculation, calculus problems tend to assume that the liquid is either ordinary water (which, by definition, has a density of 1.00* (1 kg/liter (8.35 lbs/gallon)) and a viscosity of 1.001 millipascal seconds) or a mixture mostly composed of water (depending on what exactly else it contains, such as dissolved solids or just other

* at 20°C (68°F) & sea-level air pressure

One explanation is that she was able to drill a couple dozen approx. 1-inch holes in a short time, while toxic liquid is gushing out, but the drill doesn't appear to be dripping wet.

But the most likely explanation to all this is that Randall didn't think through the drill and drill bit size in relation to the apparent hole size, leaving it only to nitpicky editors of a comic explainer website to even notice and care.

Or, the tank simply is not full at the moment the teacher drills the hole.

#2975: Classical Periodic Table

August 21, 2024
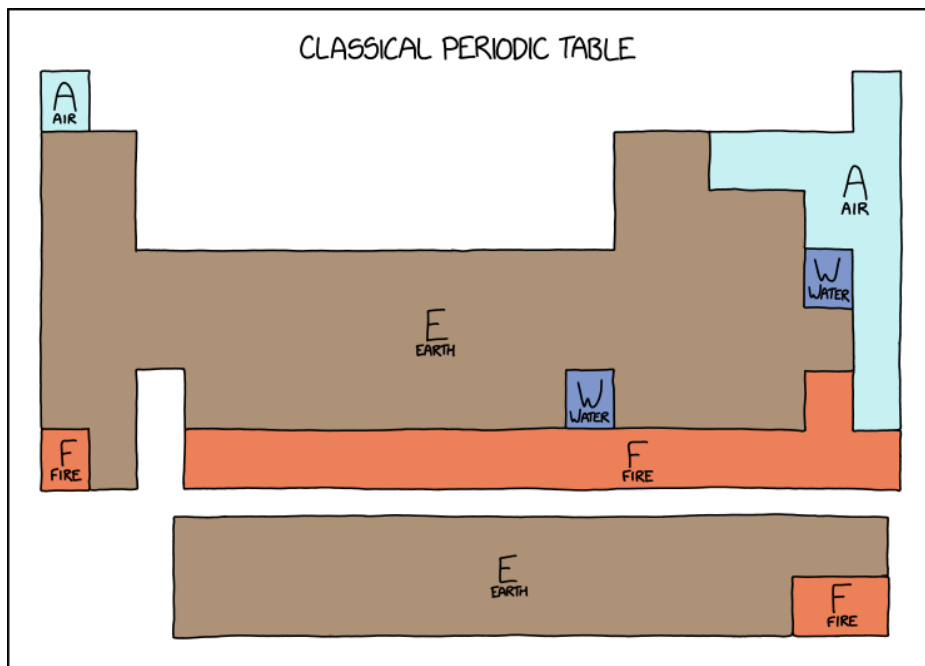
Personally I think mercury is more of a 'wet earth' hybrid element.

Explanation

An element is a basic atomic building block of the physical world. Ancient civilizations believed in a small number of broad elements. The most famous are the classical (Hellenistic) elements of earth, fire, air, water, and sometimes a fifth element such as "void", "ether", or "quintessence". The Chinese wuxing system was a bit different, dropping air and adding elements for wood and metal. Such elemental theories fell out of favor as alchemists and later scientists began to discover what we now recognize as the atomic model, and today 118 elements are recognized and organized into the Periodic Table of Elements.

Here, Randall has taken a modern periodic table and merged and color-coded the modern elements to represent the four classical elements, leaving only the edges and boundaries between dissimilar regions. Gaseous elements such as hydrogen are colored light blue for "air". Bromine and mercury, the two elements that remain liquid at room temperature and pressure, are colored dark blue for "water". Radioactive elements along the bottom of the table whose isotopes have only extremely short half-lives are red for "fire", with the rest of the chart filled in brown for "earth". The "earth" region includes many elements which are radioactive but have isotopes whose half-lives are greater than 1 day. (All elements also have radioactive isotopes with much shorter half-lives, but most of the universe's supply of any given element will tend to be its longest-lived isotope,

since others rapidly decay.)

The title text says that mercury should be classified as "wet earth". While it's a liquid, it has a very high surface tension so even large drops will stick together and may seem almost like a gel. Additionally, as evidenced by a very trustworthy source, mercury (at room temperature) is functionally a solid for many fluid purposes, including boating.

Table Sections[edit]

In actual chemistry, the symbol "W" is used for tungsten (from the germanic "Wolfram", taken from the traditional name of the ore-stone that tungsten was originally found in; "Tungsten" is of swedish origin) and "F" is the symbol for fluorine (its latin-derived name was coined for how its common minerals were used to help other smelted ores to 'flow', by lowering the melting point of the mixture). There are no chemical elements currently given the letters "A" or "E", although there are a number of two-character symbols that start with these (and also "F", but none for "W"). Argon, erbium and einsteinium were at certain times (and places) symbolically just their initial letters alone, however, in juxtoposition to "Wo" once having been used for wolfram.

The classical elements (and, as early chemistry developed, some of the earliest known current periodic-table elements) were often given pictorial symbols as a shorthand/code as befit the select, exclusive and secretive nature of that time's alchemical arts. Just one of these representations used a figurative set of triangles: upward-pointing for air and fire, downward-pointing for earth and water, with air and earth having a line across, to give , ,

and .

This comic is similar to 2913: Periodic Table Regions, which also groups elements using unconventional methods. The classical elements have been a topic of previous comics, such as 965: Elements

#2976: Time Traveler Causes of Death

August 23, 2024

TOP CAUSES OF DEATH FOR TIME TRAVELERS BY GEOLOGIC ERA:
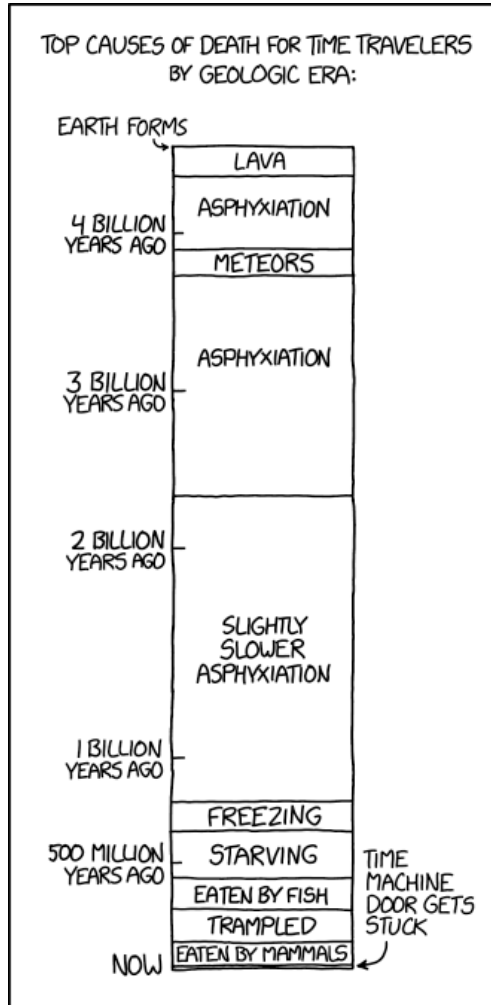
Many a hungry time traveler has Googled 'trilobites shellfish allergy' only to find their carrier had no coverage in the Ordovician.

Explanation

Time travel is a common sci-fi/fantasy plot, in which someone from one era is sent forward or backward in time to another era. Normally, the travel itself goes off without a hitch, with the usual threats to the time traveler being what happens at some point after they arrive at their destination. More rarely, a time traveler might immediately encounter some hazard because of where their time travel method has deposited them.

This comic takes the latter situation to the extreme, observing different causes of death for potential time travelers through the ages based on the geologic evolution of Earth from its formation over 4 billion years ago to the present; see detailed explanation in the table. The chart shows only the most likely cause for a given period of time, although the title text reveals that there may always be others possible.

The title text suggests that an alternative fate within the "eaten by fish" era is the exact opposite - eating something hazardous. A time traveler, having fortuitously avoided the primary "Starving" fate of the prior era, may try eating a trilobite, a kind of shellfish. They may find that either some existing allergy is triggered by this prehistoric shellfish, or that the creatures of that age spark a new allergic condition that (as a modern human) they were not previously aware they could develop a reaction against. A person with a known allergy might check for the possible presence of a problematic ingredient in a

potential snack by referencing online resources - a facility that is not available here, with the smartphone stuck in the past, long before any network is available to connect to (notwithstanding that Google Search has not existed historically for more than three decades). Alternatively, suspecting the food they've eaten has not agreed with them, they could find they are denied easy access to the best online information on how to properly treat their symptoms.

Table of death causes[edit]

August 26, 2024

THE THREE KINDS OF SCIENTIFIC RESEARCH:

WE APPLIED A STANDARD THEORY TO NOVEL CIRCUMSTANCES AND GOT SOME SURPRISING RESULTS.

WE APPLIED A NOVEL THEORY TO STANDARD CIRCUMSTANCES AND GOT SOME INTRIGUING RESULTS.

FINALLY, A MAP OF EVERY TREE.
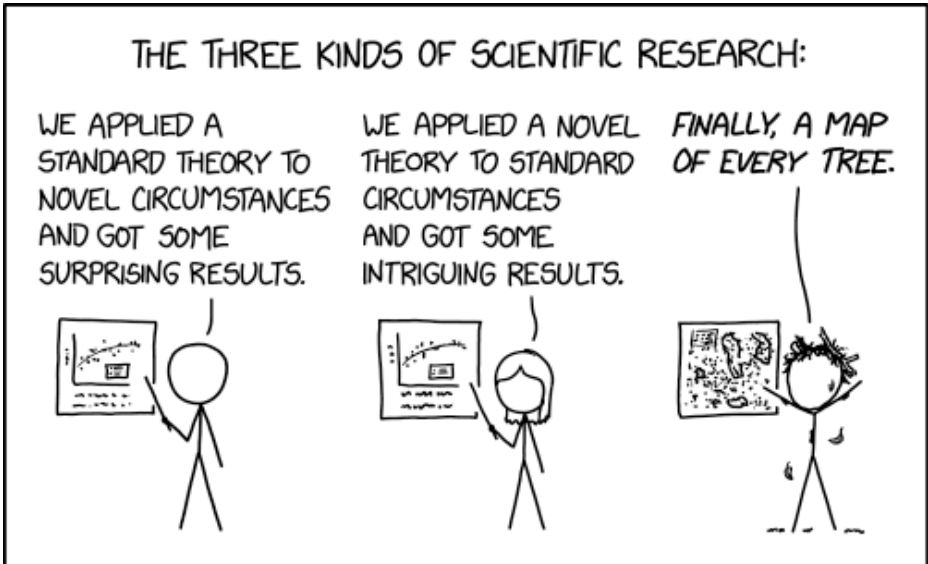
The secret fourth kind is 'we applied a standard theory to their map of every tree and got some suspicious results.'

Explanation

In this comic, three types of research are presented. First, Cueball presents an analysis of an existing theory, testing to see if it holds up under unusual circumstances. Second, Blondie presents a new theory; to prove that it has merit, it is tested on "standard" circumstances, presumably older data that the existing theories have already been tested on. As Blondie's data graph looks similar in form to Cueball's, it is possible that they are approaching the same field from two different directions.

The punchline is a disheveled Hairy presenting the third kind of research: not a theory, but a survey that collects the data to test theories on. Rather than sit around their laboratory crunching numbers, Hairy has gotten deep in the weeds — literally, judging by the leaves stuck to their body — to somehow map out "every tree." How far their survey of "every tree" reaches isn't clear but it's implied to be a massive area such as most of a country, continent or even the world (though the appearance of the graph doesn't have any obvious relationship to any global projection), and they're raising their arms in exhausted triumph over the fact that they're finally finished.

The comic thus presents a message about science: while it is perceived to be a high-minded affair with lots of very smart people performing calculations well over most people's heads, it still relies on getting down and dirty — again, literally in Hairy's case — with the rather basic challenges of measuring what the problems are to begin

with. Some scientific papers are simply descriptions of measured phenomena.

The title text brings everything together by testing theories on the tree map (this is similar to Cueball's approach), with suspicious results. There can be multiple interpretations of these results: the "map of every tree" was manipulated or simply inaccurate, someone is messing with trees on a global level or the tree survey methods and/or mapping techniques are questionable. This could also be a reference to the discovery of General and Special relativity, which sprouted from the fact that the "standard theory" at the time, Newtonian gravity, was unable to account for certain observed phenomena, such as the orbit of Mercury.

For example, the ΛCDM standard model of cosmology could be

1) supported or challenged by new empirical data on the distribution of galaxies, new simulations or a mathematical thought experiment based on that model

2) challenged by a new model that is better at explaining some oddities of the model, such as dark energy

3) complemented with a survey of the timeline of everything in the universe :-)

In this case the fourth kind of researcher would apply the cosmological standard model to the map of everything and find something suspicious.

Randall has previously created a similar type of comic in

2529: Unsolved Math Problems.

#2978: Stranded

August 28, 2024
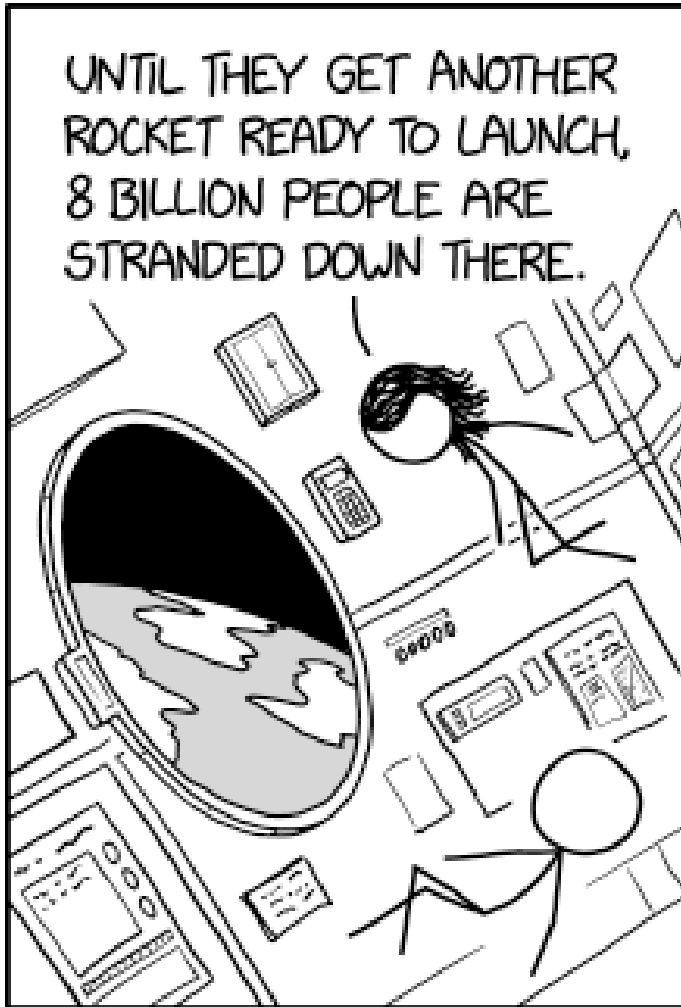
At least they're not alone down there.

Explanation

This comic is referencing the Boeing Starliner, which launched for its Crewed Flight Test on June 5th, 2024. The mission to the International Space Station was originally scheduled for only eight days, but at the comic's release, August 28, 2024, the astronauts Butch Wilmore and Sunita Williams were still "stranded" on the ISS, not expected to return to Earth until February 2025. They actually returned to Earth on March 18, 2025.

The comic points out that being stranded is a matter of perspective and circumstances; people on Earth could equally be considered "stranded", unable to get off the planet. Many science fiction stories deal with some sort of rush to evacuate the Earth, though there's usually a reason why they would wish to leave, a reason that's notably absent in the comic. Moreover, the proposed solution of one rocket would not be able to bring all 8 billion people on Earth to space.

The comic is also referencing the fact that during press conferences, NASA has stressed that the Starliner astronauts are not actually stranded, because there are procedures for emergency returns to Earth. However, the current circumstances are not dire enough to warrant this emergency procedure.

The title text references commentators saying that at least the Starliner crew aren't alone up there, as there are currently nine people aboard the ISS, but flips it around

to be about the (8 billion) people on Earth. Another funny take on the title text would be that in the turbulent times the fact that one is "stranded" like this might even be a benefit. The 8 billion people are also not alone in the sense there are numerous other species on Earth.

A comic with a similar premise is 2403: Wrapping Paper.
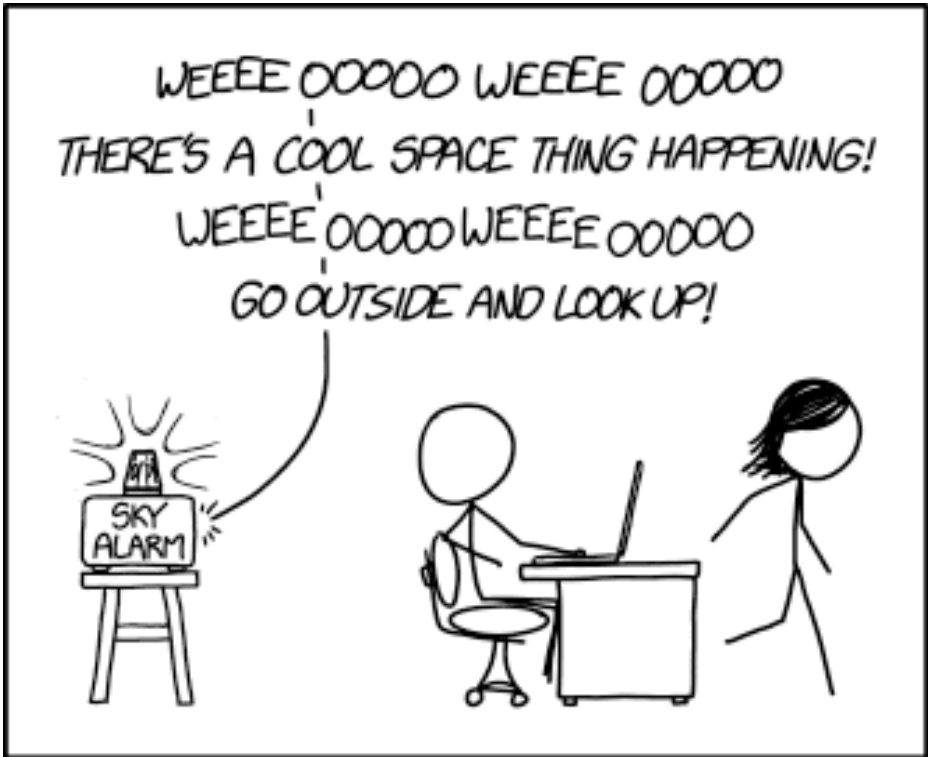
During the day it also activates for neat clouds and pretty sunsets.

Explanation

The comic shows Megan and Cueball being alerted by a 'Sky Alarm' that a 'cool space thing' is happening. The alarm is triggered when a relatively interesting astronomical event occurs, for example, the Perseid meteor shower and blue supermoon that happened recently. Randall remarks in the caption how he wants this device and wishes it existed. Cueball and Megan (and by extension Randall) feel that they regularly miss events they'd like to see, and such a device would help prevent this.

The title text further specifies that he would want it to activate even for more common sky-related spectacles, such as interesting clouds and nice sunsets (which still can be very beautiful). In short, it would help its owner to not miss interesting outdoor sights.

Most recently before this comic, Randall referred to cool sky phenomena in 2971: Celestial Event. Quite a few such references preceded this (such as the aforementioned Perseid meteor shower), so they may have been on Randall's mind.

#2980: Lava Lakes

September 02, 2024
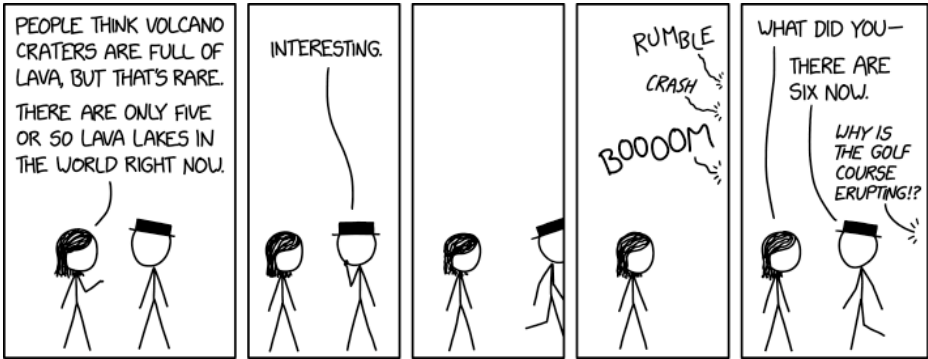
Hey, golf balls float on lava, so this should make recovering them from the hazards easier.

Explanation

The comic shows Megan talking to Black Hat, mentioning the common myth that there's a lava lake in the crater of every volcano. She points out that there are really only around five lava-filled volcano craters in the world right now.

In true Black Hat fashion, he responds to this by creating a new lava lake on a nearby golf course. Given that Megan was still waiting when Black Hat came back, the attention span of most people is shorter than the time it takes lava lakes to form and that sane people do not build golf courses directly over active volcanoes,[actual citation needed] Black Hat would've needed to dig at least 8 kilometers of earth within a very short timespan. Since this action was prompted by Megan's remark, Black Hat likely did not build or move anything capable of making a lava lake to the golf course beforehand.

The title text mentions that golf balls will float on lava, making recovering them from hazards easier (man-made obstacles such as sand or water, with sinking in the latter being the more obvious hazard to change). The density of a normal golf ball is about 1.13 grams per cubic centimeter, which is significantly less than the 2.4 ~ 2.9 grams per cubic centimeter of lava. It would be very easy to retrieve golf balls from lava because of this, if it were not for the fact that lava is hot.[citation needed] Lava is around 800 °C, while most golf balls are made of materials that ignite at 400-500 °C, and it could also be

somewhat awkward for any hand that goes to retrieve it. Not to mention that the interaction of lava with solids at STP tends to be violent. It would presumably also be extremely difficult to wipe lava from the surface of a golf ball, both while the lava is fresh and then changing to different challenges as it cools. Attempts to retrieve golf balls from lava would be profoundly dangerous, and have a vanishingly small probability of success.

These may be the 5 volcano lakes that the comic references (source):

- Erta Ale in Ethiopia
- Mount Erebus on Ross Island, Antarctica
- Kīlauea Halemaʻumaʻu on Hawaiʻi (Big Island) [no active lake in September 2024]
- Nyiragongo in the Democratic Republic of the Congo
- Mount Michael on Saunders Island, South Sandwich Islands

#2981: Slingshots

September 04, 2024

	REGULAR SLINGSHOT	GRAVITATIONAL SLINGSHOT
USED FOR HUNTING	✓	✗
USED FOR SPORT SHOOTING	✓	✗
USED FOR SPACECRAFT PROPULSION	✗	✓
LARGE ONLINE ENTHUSIAST COMMUNITY	✓	✓
MAY HAVE CAUSED DINOSAUR EXTINCTION	PROBABLY NOT	MAYBE
USED BY DENNIS THE MENACE TO TERRORIZE MR. WILSON	✓	NOT YET, BUT I'M PITCHING A REBOOT

In my reboot, Dennis the Menace was just trying to send Mr. Wilson a nice comet, but accidentally wiped out his dinosaur garden.

Explanation

The slingshot (in this comic, styled "Regular Slingshot") is primarily refering to the hand-held device used for accelerating small projectiles, such as stones or steel balls. The "forked stick and elastic" contraption (known as a catapult, in the UK) acts by a pull-back-and-release action, and has become associated with youthful recklessness (or an outright tendency towards vandalism), but is also the basis of manufactured sport/hunting devices as well as all of the more organic child-made contraptions.

The gravitational slingshot, or gravity assist, is not a device but a term used to describe how gravity can significantly alter the path of an object in space, such as a spacecraft or an asteroid. A gravitational slingshot generally involves a small object passing by a much more massive object, which turns the smaller object's trajectory, trading momentum and kinetic energy between the two bodies. The smaller object can undergo a large change in velocity, "paid for" (in the sense of conserving the momentum and energy of the system) with a negligible change in the velocity of the more massive body.

This comic humorously compares the two, in tabular format.

The first four categories accurately reflect reality. As a hunting tool (and as an offensive weapon), recent designs

have been claimed to propel a projectile with more force than .22 and .38 caliber pistols. Consequently, several communities have prohibited the possession of such slingshots, which may be called "wrist rockets". The state of Massachusetts, where cartoonist Randall resides, is one of those communities. Gravitational slingshots would be inefficient and cause overkill for such purposes, as well as being difficult to achieve sufficient accuracy and specificity.

Conversely, gravitational slingshots are a useful way to change the velocity of a spacecraft without having to use large amounts of fuel, whereas building a regular slingshot capable of propelling a spacecraft is likely to be impractical - not to mention the destructive/fatal consequences, to vehicle and cargo, of near-instantaneous acceleration to useful speeds, such as the Mach 33 required for an object at sea level to escape Earth's gravity, especially when there's an atmosphere present.

Both types of slingshot excite interest among many people who may form online communities to discuss them, but for quite different reasons, and the size of overlap between these communities is uncertain.

The fifth category ventures into the absurd, at least with respect to "regular" slingshots, which did not exist (as far as we know) at the time of the Cretaceous-Tertiary extinction event. (Humans, which invented them, did not exist at that time. Use of slingshots would therefore require some other contemporaneous intelligent species

to have invented them, or some kind of time travel.) However, it is likely that the event resulted from the impact of a space-rock that was perturbed into an Earth-crossing orbit by a planet such as Jupiter, given at least a minor gravitational slingshot on its way to eventually crashing into the Earth.

The sixth category references the long-running comic and cartoon character Dennis the Menace (USA), in which the titular character unintentionally harasses neighbor Mr. Wilson with (regular) slingshots and other devices and behaviors. In Randall's projected reboot of the franchise, which is elaborated on in the title text, Dennis trades his regular slingshot for a gravitational slingshot. By miscalibrating his ammunition, or the force of his slingshot, he turns a demonstration ("a nice comet") into a destructive event (the loss of Wilson's dinosaur garden). The reference is to the relative size and velocity of the space objects responsible for, respectively, comets and "meteors" versus asteroid impacts.

This comic is probably inspired by the recently released movie Slingshot.

This is very similar to 2844: Black Holes vs Regular Holes.

#2982: Water Filtration

September 06, 2024

HOW WATER FILTRATION WORKS
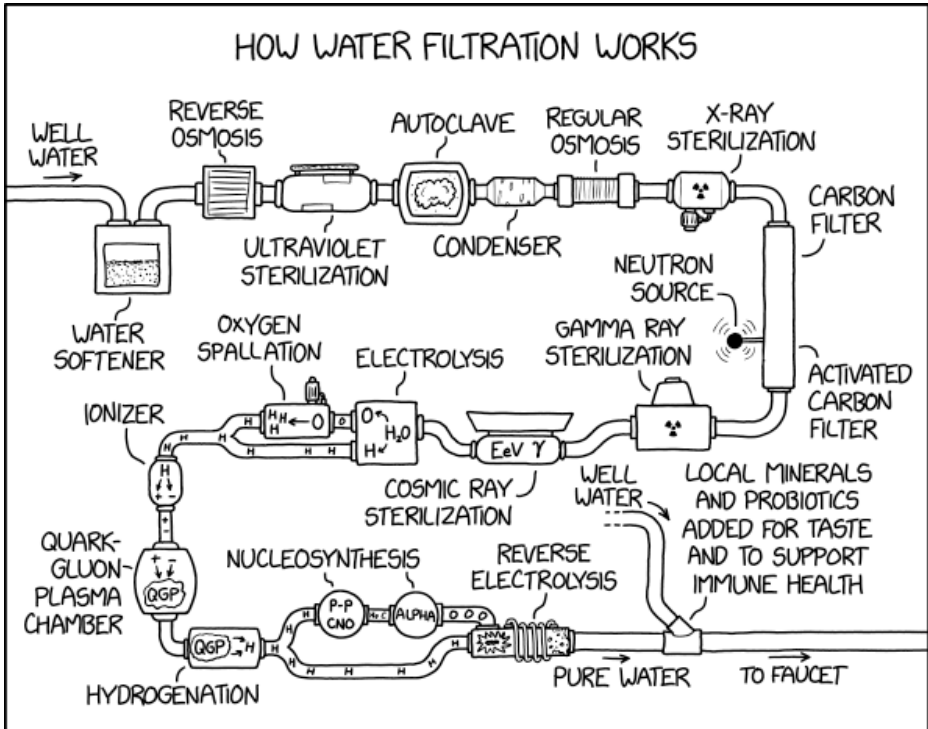
You'd think the most expensive part would be the quark-gluon plasma chamber, but it's actually usually the tube to the top of the atmosphere to carry the cosmic rays down.

Explanation

This comic seems to be a diagram of how well water is purified, a common set of procedures done to make said water safe to drink. However, this well water is "purified" through a series of increasingly unnecessary, expensive, and possibly hazardous steps, ending with producing "pure" water synthesized from hydrogen and oxygen (which have each been synthesized from subatomic particles) - before promptly undoing all of the work by re-adding raw well water and its original minerals and probiotics (which is one way of describing chemical and biological contaminants) "for taste and to support immune health". In real life, groundwater generally only needs treatment for any contaminants (chemical or biological) known to be a problem based on the results of water testing or an incident, but adding the original water back in could be dangerous if the water has not been sampled recently.

The title text briefly covers the cost implications of the components. Various 'real' filter elements will have material or energy costs or both, in operation or to replenish their effectiveness, and the high energy input needed to disassociate hadrons into raw quark–gluon plasma (at bulk levels) would seem to require the most in terms of running the equipment. But it is pointed out that to ensure enough cosmic rays reach that particular phase of sterilization, there would have to be a pipe (not shown) leading out to the edge of the atmosphere to optimistically carry down such particles (due to also

containing no air, i.e., keeping it out to negate the normal shielding and dissipating effect of the atmosphere on cosmic rays). However, this pipe would not only be a flight hazard, but also to ensure that no air molecules get in, the pipe would have to be similar to a space elevator, which would wreak a lot of havoc on LEO and MEO.

Whether a one-off cost or needing regular replacement, the setting up of such a tubular structure (a vertical air-proof pipe perhaps somewhere between 100 and 10000 kilometers high) would be technically challenging and has not ever been actually accomplished. The conditions for a quark–gluon plasma, albeit in limited quantities, at least have been fulfilled at CERN, with its 27 kilometer airless pipe that goes round within a vast circular tunnel.

#2983: Monocaster

September 09, 2024
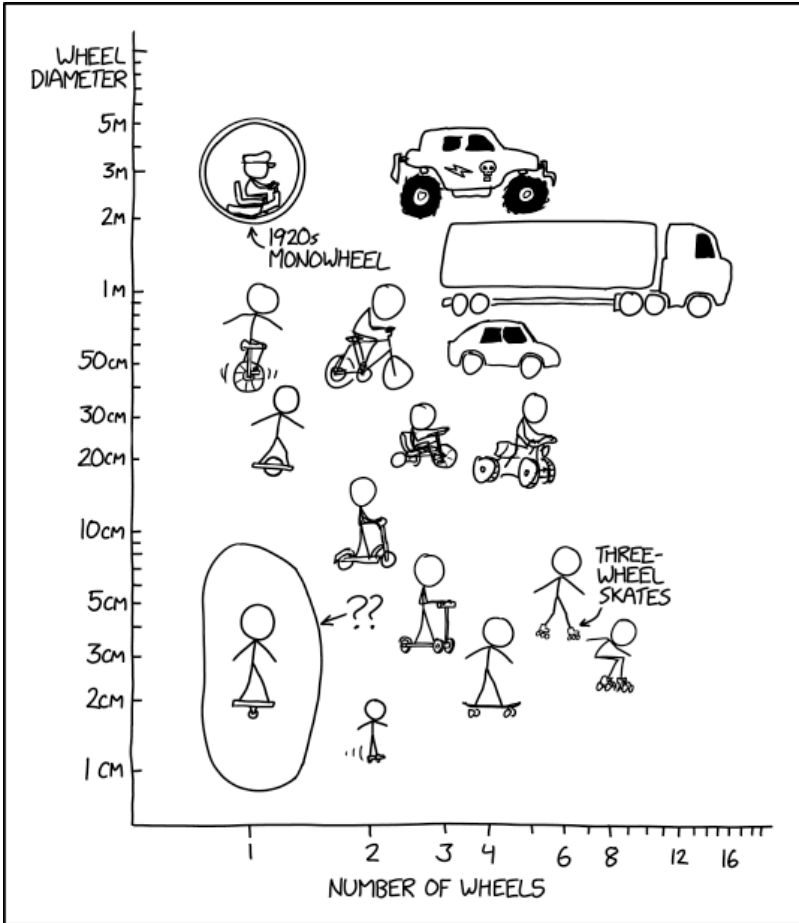
MY NEW MONOCASTER BOARD FILLS A KEY
GAP IN THE WHEELED VEHICLE MARKET.

My competitors say the tiny single tiny caster is unsafe, unstable, and offers no advantages over traditional designs, to which I say: wow, why are you guys so mean? I thought we were friends!

Explanation

A caster, also spelled castor, is a small unpowered wheel, usually attached to a swiveling base. They are typically found on carts and office chairs to make them easy to move, and may be placed on heavy appliances to facilitate movement.

Randall has proposed a variant of the skateboard with only one caster on the bottom, the titular "monocaster", and devoted most of the comic to a perceptual map showing the variety of wheeled vehicles. Market strategists and investors use such diagrams as a simple way of representing important differences between products or companies, but where a consumer might be more concerned with features like speed, cost, ease of use, or carrying capacity, this map focuses on the number of wheels (horizontal axis) and the diameter of those wheels (vertical axis).

Each axis uses a logarithmic scale, which is convenient for making the map look more evenly filled but also visually exaggerates the size of the "key gap" that the monocaster is filling, which can be described as "vehicle with a single wheel smaller than 25 cm". The nearest competitors appear to be a two-wheel skateboard sometimes called a caster board (wheel diameter under 8 cm) and a single-wheel self-balancing board resembling a Onewheel (diameter around 25 cm). The Onewheel is sometimes described as a monowheel (though these are traditionally larger like the "1920s monowheel" on the upper left).

Randall appears to have combined these two names to create the monocaster. This gives up several of the competitors' features - the caster board's two wheels provide enough stability to propel the vehicle manually, while the Onewheel's single wheel is wide (assisting with sideways balance) and powered by a self-balancing mechanism.

The result resembles a "Sphere-and-ring" balance board, or other types, though these provide limited locomotion potential. The joke depends on the caster's obvious impracticality in this role: the hole in the market was open for a reason. The obvious drawback to any single-wheeled vehicle is that it's difficult to balance: the rider has to avoid falling forward or backward, as well as to either side. This is a major reason why one-wheeled vehicles are uncommon to begin with, but those vehicles which do exist compensate by using relatively large wheels, driven either by human power or a motor, which creates rotational inertia and allows the rider to balance simply by leaning forward.

A single, small, undriven wheel eliminates these balancing forces, meaning that the user would essentially need to balance on a single point. Also, most casters swivel, meaning that the balance point would move around under the rider's feet and make it even more difficult to balance. In addition, there's no apparent means of propulsion, which means the only way to move forward would be to either roll exclusively downhill, or use one foot to push off the ground. Either strategy would make retaining balance almost impossible.

Multiple-wheeled vehicles greatly reduce the issue of balance simply by having multiple points of contact with the ground. The size of the wheels varies greatly; small, rigid wheels are generally suitable only for flat, smooth, rigid surfaces at relatively slow speeds, while vehicles expected to handle high speeds and varying road (and off-road) conditions will necessarily have larger wheels.

The "monocaster" design offers no advantages and would be nearly unrideable, making it obvious why such a vehicle has never been seriously proposed.

The title text extends the joke by listing the disadvantages mentioned above, but not providing a rebuttal. Instead it only attempts an emotional appeal by saying that the competitors are being mean and by commenting that Randall believed they were friends.

(*) It seems that Randall has made some mistakes in regards to the wheel sizes, especially in the centimeter range of the diagram. Most of the vehicles have bigger wheels and the number would suggest hat he meant inches instead of centimeters. Alternatively, he may have mistakenly recorded the wheels' radius instead of its diameter, as intended.

#2984: Asteroid News

September 11, 2024

ASTRONOMERS INITIALLY SAID THERE WAS A ONE-IN-6,000 CHANCE THAT THE NEWLY-DISCOVERED ASTEROID MIGHT "DO SOMETHING COOL" IN 2063, BUT FURTHER OBSERVATIONS DETERMINED IT WILL BE "JUST A BORING DOT LIKE ALL THE OTHERS."
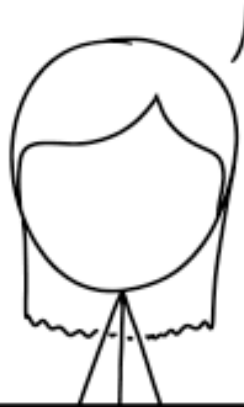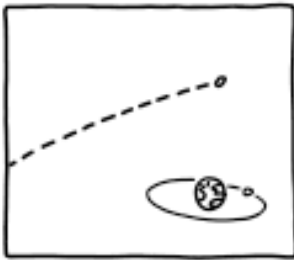
Their calculations show it will 'pass within the distance of the moon' but that it 'will not hit the moon, so what's the point?'

Explanation

Blondie as a news anchor presents an image where an asteroid is seen zooming past Earth outside of the Moon's orbit.

The comic is about an unspecified asteroid that is predicted to approach Earth in 2063. It could possibly be related to the recently discovered asteroid 2024 MK, which made a close approach to Earth on June 29, 2024, but it could be any of the Sentry Objects of the Jet Propulsion Laboratory's Center for Near Earth Object Studies .

Blondie mentions that according to the astronomers, the asteroid only has 'a one-in-6000 chance of "doing something cool",' meaning that there is only a small chance that the asteroid will have a direct impact on Earth's surroundings. What is described as "something cool" would presumably be that the asteroid hits or almost hits the Earth or the Moon. She then states that further observations have shown that this will not happen and the asteroid will just be yet another boring dot in the sky.

The joke is that most people are afraid that a near-Earth asteroid would actually hit, and hope to hear that it will not. If the asteroid in this comic gets close enough that it will actually be a visible dot, then given the normal sizes of near-Earth asteroids, it would indeed be very close to Earth. Many people interested in the night sky would

find it interesting to see an asteroid with their naked eye.

The title text may refer to another asteroid that gets even closer than the one depicted, because this one should come closer than the Moon according to calculations (presumably by the astronomers). However, this asteroid will not hit the Moon even though it gets close, so the astronomers ask, "What's the point?". The comic is mute on the question whether the asteroid will hit the Earth, although this is generally very unlikely even for an asteroid passing closer than the Moon. Again Blondie implies that the astronomers hope for some visible effect.

This is the fourth comic in the last seven about space.

#2985: Craters

September 13, 2024
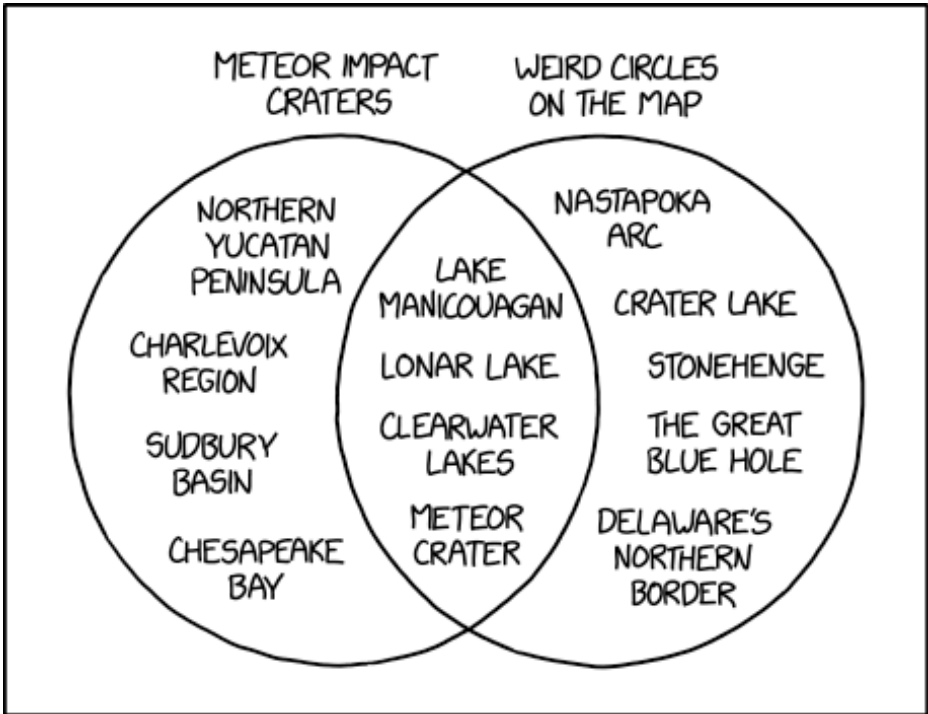
It's annoying that the Nastapoka Arc isn't a meteor impact crater, but I truly believe that--with enough time, effort, and determination--we could make it one.

Explanation

This comic uses a Venn diagram (itself composed of large circles) to classify large circles on the ground into meteor impact craters, "weird circles on the map", and both.

The Nastapoka Arc was most likely caused by continental plates crashing into each other rather than a meteor impact. However, in the title text Randall believes that it COULD be an actual meteor impact site with enough dedication: he wants to redirect an asteroid into Hudson Bay, which is a bad idea.[citation needed] There is no efficient way to artificially direct asteroids towards Earth, let alone ones large enough to make the appropriate size hole. The Double Asteroid Redirection Test (DART) slightly changed the orbit of one asteroid around another by slamming a spacecraft into the asteroid; doing any more substantial redirection would require applying a great deal of impulse to an asteroid, which has never been done. Moreover, the precision required would be a massive obstacle: a small variance in timing or angle would make the asteroid hit Earth in the wrong manner, at the very least creating an improperly matched hole (for size and shape), with the most likely outcome being to miss the original feature entirely. There is also the potential to slam into nearby populated areas, but some historic circular features are themselves populated so would suffer directly in the case of a perfect impact. Attempting to do so would be costly and potentially cause massive devastation.

This idea of directing an asteroid to directly impact the Earth is on some level an inversion of disaster movies like Armageddon, where an asteroid is landed on to destroy or deflect it; Armageddon was mentioned in 1740: Rosetta and 2729: Planet Killer Comet Margarita.

#2986: Every Scientific Field

September 17, 2024
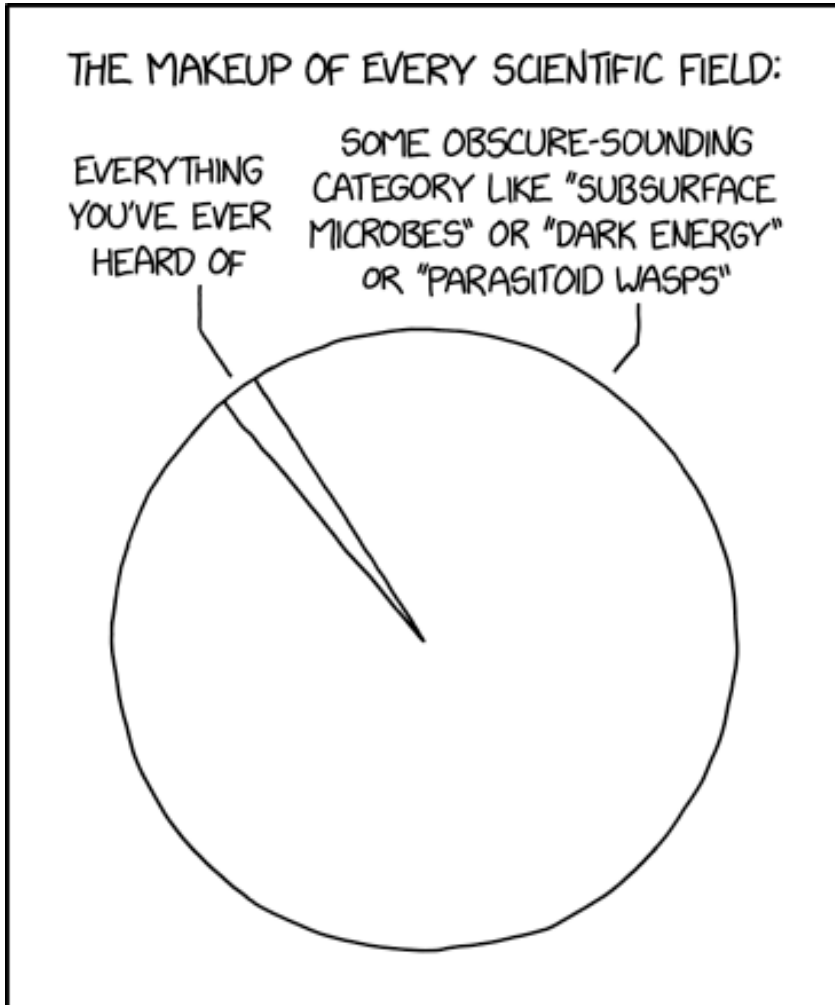
Conveniently for everyone, it turns out that dark energy is produced by subterranean parasitoid wasps.

Explanation

Randall uses this pie chart to show that more than 95% of scientific topics are actually unknown to the general public, and he has listed three topics within the larger fields of cosmology, microbiology, and entomology as examples of obscure but consequential areas of research:

- "Dark energy" is the term used for the unknown cause of the accelerating expansion of the universe. It behaves like energy; if it is an energy, it contributes 68% of the total energy in the present-day observable universe.
- The deep biosphere resides below the first few meters of the ground down to at least 10 and 21 km below the continental and sea surfaces respectively. The subsurface accounts for about 90% of the biomass across two of the three domains of life, Archaea and Bacteria.
- Parasitoid wasps lay their eggs on or in the bodies of other arthropods, sooner or later causing the death of these hosts. They are a huge group, with the subgroup of Chalcidoidea alone comprising an estimated 500,000 species.

The three categories listed in the comic are not random examples of obscure-sounding scientific knowledge; the terms themselves each have a subtle and clever double meaning for what counts as "obscure" knowledge:

- The adjective "dark" can also describe a situation

notable for a paucity of knowledge, as in the "dark ages" or the "dark web", just like the "dark energy" form of energy is little known by the layperson.

- The adjective "subsurface" connotes a world below the surface, just as laypeople are unaware of the world of biomass below the everyday surface of common knowledge. It's a similar metaphor to phrases like "sub rosa" — literally "under the rose" — and "undercover," which refer to actions done in secret.

- Parasitoid wasps act covertly; their larvae can grow inside an insect — like a caterpillar — secretly, with no clear indication that the innards of the caterpillar are being slowly replaced with a wasp larva, similar to the hidden nature of this giant class of insects to the common layperson.

The title text jokingly wraps these three examples together.

Evidence for this phenomenon in science news[edit]

According to the American Association for the Advancement of Science, nearly 3 million scientific research papers were published in 2022, the latest year for which numbers are conveniently available. A tiny percentage of these studies find their way to "general news" outlets, which, according to a 2017 report by the Pew Charitable Trust, are the principal sources of science news for non-scientists. According to that same report, "general news" sources preferentially cover scientific research findings that make "newsworthy" discoveries, are "weird", or have "human interest" dimensions such as disagreements among celebrity scientists. There is also a bias towards certain topics, such as health and

medicine. Consequently, vast domains of "science space" go unreported by general news, and hence are unknown to the general public.

#2987: Tectonic Surfing

September 18, 2024
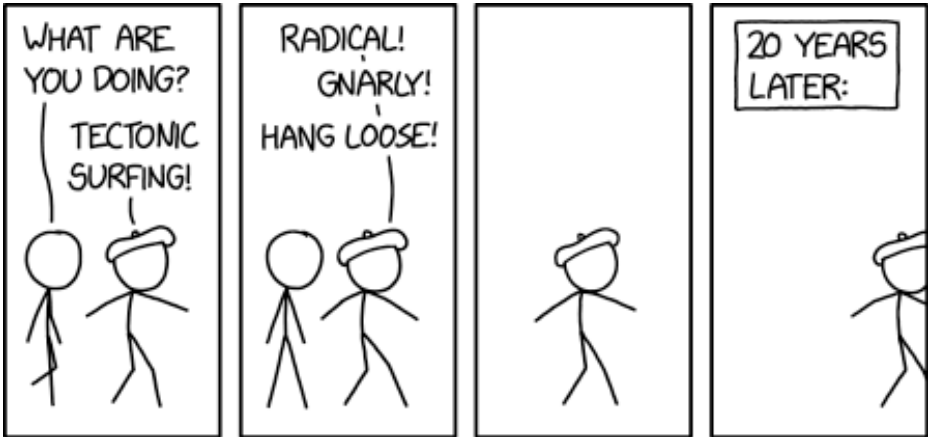
The worst is when you wipe out in the barrel and you're trapped for several million years until erosion frees you.

Explanation

Surfing is a sport where the participant tries to stand or otherwise remain stable on a moving surface as long as possible. Traditionally the name "surfing" refers to riding a surfboard that is itself floating on the ocean waves as they crash into shore, but in colloquial English it is possible to "surf" other things such as a crowd of people, the floor of a moving bus, a subway car, or the Internet.

In this comic, Beret Guy is surfing the Earth's tectonic plates. Tectonic plates move very slowly compared to a normal surfing experience — so slowly, ordinary people perceive them to be stationary ground. But Beret Guy, in typical Beret Guy fashion, sees the broader picture in the most whimsical way possible and is now surfing the plates across the Earth's mantle below. He seems to be moving horizontally at about 4-5 cm/year (~1 m/20 yrs) which would put him on one of the moderately fast plates, at least relative to the more stable North American plate. For comparison, the fastest-moving plate, the Pacific Plate, would move about two meters in 20 years relative to the African Plate (which is used as the standard which all other plate motions are measured against).

While doing this he says "Radical", "Gnarly", and "Hang loose" which are exclamations commonly used among surfers. After 20 years, he is still standing there, having moved about one meter with the continental plate. This is thus another of the strange powers of Beret Guy —

being able to stay in place for 20 years. This was also seen in 1088: Five Years, where he waited five years to find out where he would be after that time.
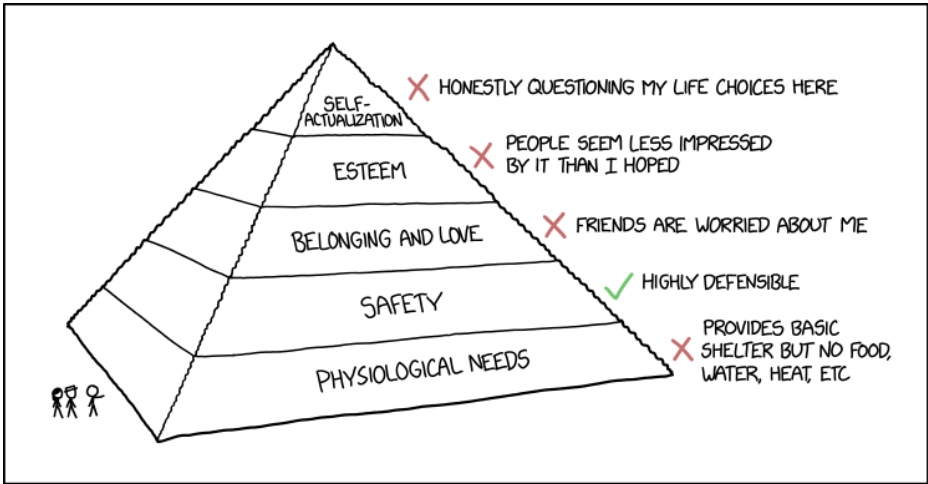
The title text refers to riding the barrel, in which one surfs inside the hollow part of a breaking wave, while a wipe out means you get swept off your surf board. If you wipe out in a barrel, you most likely submerge under water. If this were possible in tectonic surfing, you would be stuck under a tectonic plate and you would have to wait until the material you're trapped in erodes. In reality, there's no such thing as breaking waves in plate tectonics, but there are geological folds that can be seen as similar to the way that turbulent water mixes. Things do get trapped when two tectonic plates collide in a process called subduction, in which one plate disappears below another.

Of note, Beret Guy is mentioned to have a "subduction license", as seen in 1388: Subduction License, so he may have some recourse in such a situation. Due to said license, he would survive and reemerge from the continental plate barrel in a million years time.

A previous comic about tectonics being slow is 2061: Tectonics Game.

#2988: Maslow's Pyramid

September 20, 2024

SELF-ACTUALIZATION ✗ HONESTLY QUESTIONING MY LIFE CHOICES HERE

ESTEEM ✗ PEOPLE SEEM LESS IMPRESSED BY IT THAN I HOPED

BELONGING AND LOVE ✗ FRIENDS ARE WORRIED ABOUT ME

SAFETY ✓ HIGHLY DEFENSIBLE

PHYSIOLOGICAL NEEDS ✗ PROVIDES BASIC SHELTER BUT NO FOOD, WATER, HEAT, ETC

I BUILT MASLOW'S PYRAMID THING, BUT IT'S A TOTAL RIPOFF—IT'S ONLY PROVIDING 20% OF MY NEEDS.

The local police, building inspector, and fire marshal are all contesting my 'safety' assertion, or would be if they could reach me past all the traps.

Explanation

Maslow's hierarchy of needs is a psychological model initially proposed by Abraham Maslow in 1943. It posits that all humans have certain requirements for a healthy and fulfilled life, and that these can be prioritized by how fundamental and foundational they are. The most basic needs are physical, such as food, water, and shelter, as humans can't survive without them in the long term. Then come things like safety, which includes physical safety, but also protection from things like emotional and economic threats. Beyond these come less urgent needs, such as love and social belonging, with the top (at least in simplified versions) being "self-actualization" or something similar.

The idea is frequently represented by a segmented triangle diagram, with basic foundational needs near the bottom creating the stability to enable self-actualization at the top, at least in the 'simplified' version. This diagram has become so popular that it's commonly referred to as "Maslow's Pyramid", even though Maslow himself never actually used the term.

In this comic, Cueball has interpreted the concept of Maslow's Pyramid literally. He attempts to achieve true happiness by building an actual, physical pyramid that resembles the common representation of Maslow's hierarchy. Cueball complains that the pyramid only fulfills one of the five needs listed on its side: physical safety, as it's "highly defensible". However it seems it

completely fails to provide Cueball with Self-Actualization, Esteem, Belonging and Love. It can also potentially provide shelter, but that's only one of multiple physical needs.

The pyramid is useless for his social and emotional needs: everyone, like Megan and White Hat whom he shows his pyramid to and including Cueball himself, thinks the pyramid was a poor idea. Despite the impressive accomplishment of constructing such an edifice, Cueball apparently feels entirely unfulfilled, and is "honestly questioning [his] life choices".

The pyramid's size can be estimated thanks to Cueball standing close to it. A single tier appears to be roughly two Cueballs in height (meaning that with Cueball being 1.7m to 2.0m tall, the 5-tier pyramid would be 17-20m tall, equivalent to a building with about six or seven storeys) and the base appears roughly 16 Cueballs in length (meaning 27-32m wide, potentially covering an area of ~700-1200m²). Compared to famous Egyptian pyramids that is a rather modest monument but it would be comparable to the Louvre Pyramid in size.

The title text calls into question the notion that it provides even physical security. It apparently fails to comply with fire and building codes, which is potentially dangerous to both Cueball and his community. Moreover, he implies that inspectors can't even access the building, due to "all the traps". The notion of real-life pyramids (and other ancient structures) being filled with active booby-traps is commonly portrayed in fiction, and

it seems that Cueball built such traps into his pyramid. Of course, in a modern structure, such traps would almost certainly be illegal on their own (particularly if they prevented authorities from accessing the property), and living in a pyramid full of traps would potentially be a danger to Cueball himself. Even if the structure provided physical safety, if it put him in legal jeopardy (and likely economic danger, considering how expensive it must have been to build), means that it doesn't even fulfill that need.

#2989: Physics Lab Thermostat

September 23, 2024
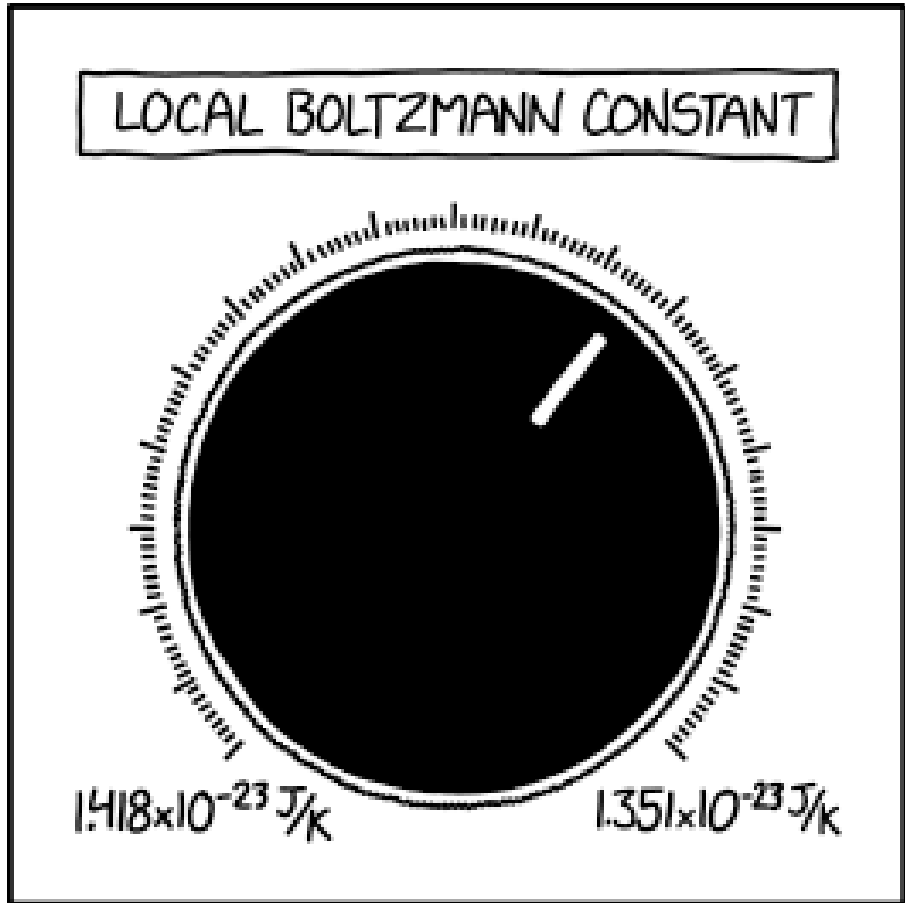
PHYSICS LAB THERMOSTAT

Hopefully the HVAC people set it to only affect the AIR in the room.

Explanation

This comic is about a thermostat in a physics lab which, instead of controlling the air temperature, adjusts the Boltzmann constant in the immediate area, a value relating temperature to energy equal to 1.38×10−23 J/K, where J is joules, a unit of energy, and K is kelvin, a unit of temperature. The dial shows different values for the constant, implying that it can be changed, which would be disturbing as a lot of what our current understanding of physics assumes it can't be. Thankfully, in reality there is no way to change the Boltzmann constant, so the comic is making fun of the idea of a scientist casually adjusting a fixed law of physics as if it were something simple like room temperature.

If the Boltzmann constant could be changed, it would affect how we experience temperature. The energy range on the dial relative to the actual Boltzmann constant might correspond to (or feel like?) apparent temperatures of 15°C (59°F) on the left, to 29°C (84°F) on the right, because raising the value of the constant would decrease the apparent temperature. There have previously been control panels for properties of the universe in 1620: Christmas Settings and 1763: Catcalling. A thermometer including units compatible with this thermostat (after dividing by 2/3) is shown in 2292: Thermometer.

The title text builds on the absurdity of being able to adjust the Boltzmann constant. It suggests that if the constant could be changed, hopefully it would only

affect the air in the room and not other substances. In particular, the metabolism of the room's occupants is hopefully unaffected. Imagining that this strange version of an HVAC (heating, ventilation, and air conditioning) system could contain such a change to just the room's air shows the ridiculousness of trying to isolate the effects of altering a universal constant.

#2990: Late Cenozoic

September 25, 2024

SPECIES SUCH AS TRICERATOPS AND TYRANNOSAURUS BECAME MORE RARE AFTER THE CRETACEOUS, BUT THEY SURVIVED TO FLOURISH IN THE LATE CENOZOIC, 66 MILLION YEARS LATER.

MANY COMPLETE SKELETONS HAVE BEEN DISCOVERED FROM THIS ERA.
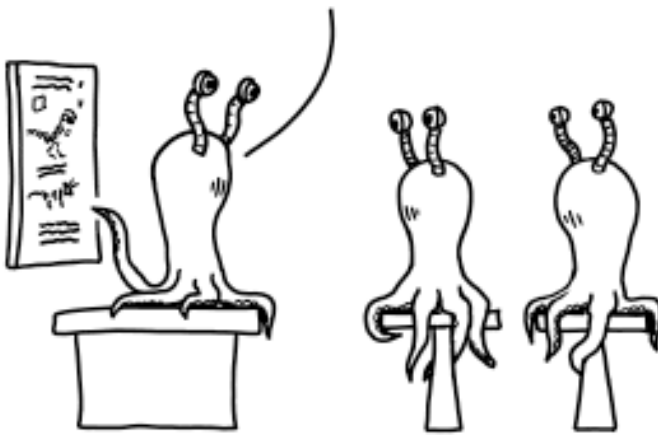
IT'S GOING TO BE REALLY FUNNY WHEN OUR MUSEUMS GET BURIED IN SEDIMENT.

Our nucleic acid recovery techinques found a great deal of homo sapiens DNA incorporated into the fossils, particularly the ones containing high levels of resin, leading to the theory that these dinosaurs preyed on the

once-dominant primates.

Explanation

A major part of understanding how life-forms existed and operated in the past involves finding fossilized remains, and working out a timeline of when they lived, based on the sediment layers in which they were found (among other factors). Modern paleontology has resulted in many of these fossilized remains being dug up and assembled into complete skeletons, which are frequently put on display in museums and other facilities.

This comic posits a future in which the remains of current civilization become buried in sediment, likely as a result of humanity going extinct so as to allow the premise of this comic to occur. Modern science estimates nearly all human-made activity - glass, concrete, steel - would erase to nothing within at most 1000 years (see Life After People and The World Without Us), meaning that any future life-forms, extraterrestrial or evolved modern-day species, would be hard pressed to find anything that suggested this planet used to be inhabited by humans, save for some microplastics, nuclear waste and, in this scenario, preserved dinosaur bones, apparently.

While a question may arise as to why exactly no dinosaur fossils can be found in the intervening ~66 million years (which we know is because they went extinct and later ones were actually dug up by a different species), the real-life fossil record is quite sporadic, meaning such gaps should not be seen as unusual (these gaps are termed

Lazarus taxons).

The title of the strip refers to the Cenozoic era, which is the current geological era. The term "late Cenozoic" implies some geological change would occur significant enough to warrant designating a new era; either these changes led to the end of human civilization or are in fact spurred by them.

The title text says that a high amount of resin and human DNA found in these fossils led to them theorizing dinosaurs ate humans. When reconstructing fossils, resin is often used to recreate missing or incomplete bones amongst other purposes in assembling and displaying a "complete" skeleton. Since this resin is made and mixed by humans,[citation needed] incidental human DNA sources (such as cast off skin cells and hair) almost certainly get mixed in, leading to this misconception.

A similar museum, misunderstood by humans instead of this other species, is depicted in 2760: Paleontology Museum.

#2991: Beamsplitters

September 27, 2024
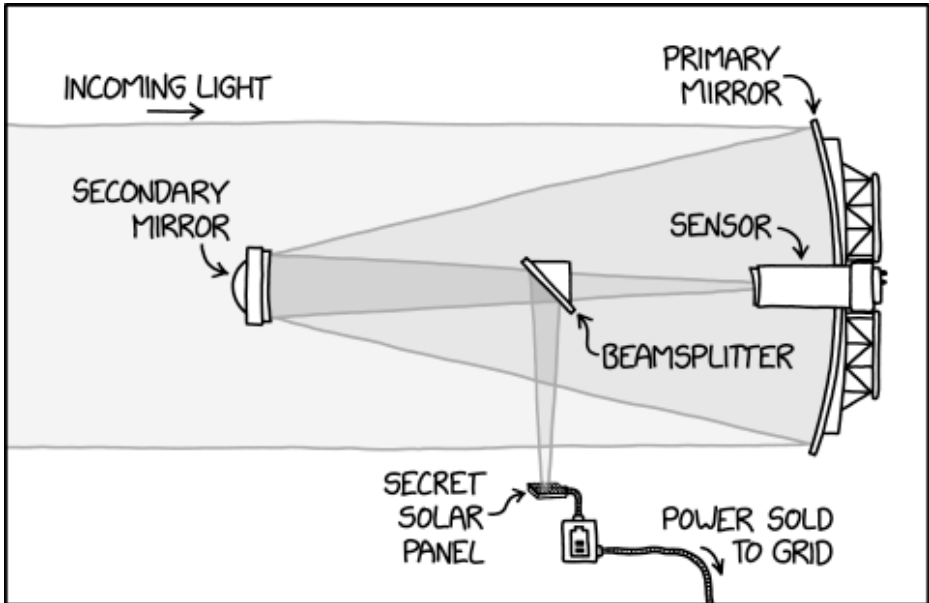
ASTRONOMY NEWS: THE INTERNATIONAL ASTRONOMICAL UNION HAS FINALLY BANNED BEAMSPLITTERS, OPTICAL DEVICES USED BY SCIENTISTS TO EMBEZZLE LIGHT FROM THEIR INSTRUMENTS.

Under quantum tax law, photons sent through a beamsplitter don't actually choose which path they took, or incur a tax burden, until their wavefunction collapses when the power is sold.

Explanation

A beamsplitter is a device, usually made from a pair of prisms or a half-silvered mirror, that splits a beam of light into two beams going in different directions. Beamsplitters are used in numerous scientific instruments such as microscopes and (here) telescopes. In a microscope, for example, a beamsplitter may be used to direct the imaging beam to the user's eyes, or to a recording device such as a camera, or to both at once so as to allow visual aiming at specific targets at the same time as conducting scientific measurements upon them. Beam-splitting in order to simultaneously analyse a single 'ray' of light with two or more different types of detectors is also scientifically useful.

In this comic, a beamsplitter is being used in a large-scale telescope to "steal" part of the incident light beam and direct it to a photovoltaic cell. The power generated is then sold on the local grid. The scientists could be pocketing the proceeds, or possibly using them to help pay the telescope operation's bills. This could be dark humor, implying that surreptitious and legally/ethically questionable strategies are needed to fund scientists and their projects. The comic pushes the point by supposing that the practice had become so commonplace that the International Astronomical Union (IAU) got wind of it, and has acted to ban it.

Most optical instruments, even large telescopes, are unlikely to capture enough light during regular

operations to make the "banned" strategy feasible. (Far more light would reach the solar cell if it was simply left outdoors, even on a cloudy day.) Moreover, the ban is ham-fisted, as it makes legitimate scientific operation of telescopes profoundly more difficult. For the sake of the joke, both of these issues are ignored.

The telescope shown, without the beam splitter, is a reflecting telescope of the general form of a Gregorian telescope, or a derivative, while the sending of (a fraction of) the light out the side is implemented in the manner of a Nasmyth telescope.
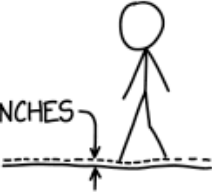
The title text humorously conflates financial tax laws, applicable to the sale of the "stolen" electricity, with the laws of quantum physics, governing the behavior of the photons that are generating the electricity. Under typical capital gains tax laws, certain intangible assets such as stocks are not taxed until they are sold, at which point taxes will be levied on the profits of the sale (relative to the asset's purchase price). This is typically done to simplify tax assessment, as it can be very difficult to assign a concrete value (and thus tax burden) to certain assets until they are sold and the value realized.

The title text imagines a fictional "quantum tax law" in which individual photons are treated as taxable assets. Due to the probabilistic nature of the photon's wave function, the monetary value of any given photon entering the telescope is uncertain up until the point where it strikes the photovoltaic cell, generating an electron which is sold to the power grid. Under the

quantum tax law, the "wavefunction" of the photon refers not to its traditional quantum wave function, but to the monetary wavefunction which can only be observed once the photon has generated a tangible profit. This is likely an analogy with capital gains tax which does not accrue until assets are sold at a profit over their purchase price.

#2992: UK Coal

September 30, 2024

$$\frac{\text{UK TOTAL COAL PRODUCTION (1853-PRESENT, UK DESNZ)}}{\left(\begin{array}{c}\text{COAL SEAM}\\\text{DENSITY}\end{array}\right) \times \left(\begin{array}{c}\text{UK LAND}\\\text{AREA}\end{array}\right)} = \frac{25 \text{ BILLION TONNES}}{1.3 \frac{kg}{L} \times 240{,}000 \text{ km}^2} \approx 3 \text{ INCHES}$$

THE UK SHUT DOWN THEIR LAST COAL POWER PLANT TODAY, WHICH MEANS THAT OVER THE COURSE OF THE INDUSTRIAL REVOLUTION, THEY DUG UP AND BURNED AN AVERAGE OF 3 INCHES OF THEIR COUNTRY.

The Watership Down rabbits removed an additional 0.1 nanometers constructing their warren, although that was mostly soil. British rabbits have historically mined very little coal; the sole rabbit-run coal plant was shut down in the 1990s.

Explanation

This comic uses dimensional analysis to describe the end of coal-powered energy production in the United Kingdom, in reference to the shutting down of the Ratcliffe-on-Soar coal power plant in central England on Monday, September 30, 2024. This event signified the closure of the last coal-fired power plant in the UK. This is an important milestone in global energy use, because the United Kingdom was at the forefront of the Industrial Revolution, which began an era of large-scale coal extraction to fuel the world's industries. Over the course of the past several decades, coal has increasingly fallen out of favor, with natural gas becoming a more viable power source, and an increasing percentage of energy needs being met without the use of fossil fuels (from sources such as nuclear, hydro, solar and wind power). The fact that the UK has now fully transitioned away from the use of coal as a major energy source marks a major shift in how industrialized nations are powered.

UK coal production has also been in decline significantly since the politically enforced decline in the 1980s, and the proposed opening of the new Woodhouse Colliery in Cumbria seems to have been stopped, leaving just the remnants of the coal-mining industry active. There remain uses for coal, both locally obtained and imported, but the conversion away from coal in various industries marks a possible soft-end to the era of coal use in Britain. The equation shown in the comic determines how much coal was mined in the UK with respect to the surface area

of the region, and calculates that this represents the removal of an average of about 8.0 cm (in imperial units, 3.2 inches) across the whole of the United Kingdom. This is another example of Randall doing unusual unit cancellation, as seen for instance in the What If? chapter Droppings. The accompanying picture implies that this coal has actually been removed in an even layer across the surface area of the country, resulting in ground level now being three inches lower. In reality, coal is extracted from deposits in specific locations, leaving other areas generally unaffected. Also while some of it has been open-cast mined, leaving visible quarrying scars (that may have been partially relandscaped), much of it has been mined sub-surface, with minimal effect on the surface itself, except where it may cause localized subsidence, sometimes of significant depth.

The calculation can be performed as follows:

- UK total coal production: 25 billion = 25,000,000,000; tonnes = metric tons = 1000kg. So 25 billion tonnes = 25,000,000,000,000kg

- coal seam density: 1L = 0.001m3. So 1.3kg/L = 1300kg/m3.

- UK land area: 1km2 = 1,000,000m2. So 240,000km2 = 240,000,000,000m2.

- 25,000,000,000,000/(1300 * 240,000,000,000) = 25,000,000,000,000/312,000,000,000,000 = 25/312 = 0.08

- kg/[(kg/m3)*m2] = 1/(m2/m3) = m3/m2 = m

- 0.08m = 8cm = 3.2 inches (1 inch = 2.54cm)

UK DESNZ, referenced in the comic, is the United Kingdom's Department for Energy Security and Net Zero, the source for the statistic on UK total coal production from 1853 to present; see DESNZ's historical statistics of coal production here.

Since Randall is warning about climate change in several of his comics, he likely sees this as an important step away from the use of fossil fuel.

The comic's title text adds a similar, but even more ludicrous, metric for earth excavated for a rabbit warren. The volume of earth described, 0.1nm × 240,000km2, is equal to 24m3 (≈ 31 cubic yards). The text refers to Watership Down, a 1972 novel about a group of English rabbits. (A sole sequel to Watership Down, Tales from Watership Down, was published in 1996.) The text also refers to a former rabbit-run coal plant in the UK and claims that it was shut down in the 1990s. No actual rabbit-run coal plants have ever been documented.[citation needed]

#2993: Ingredients

October 02, 2024
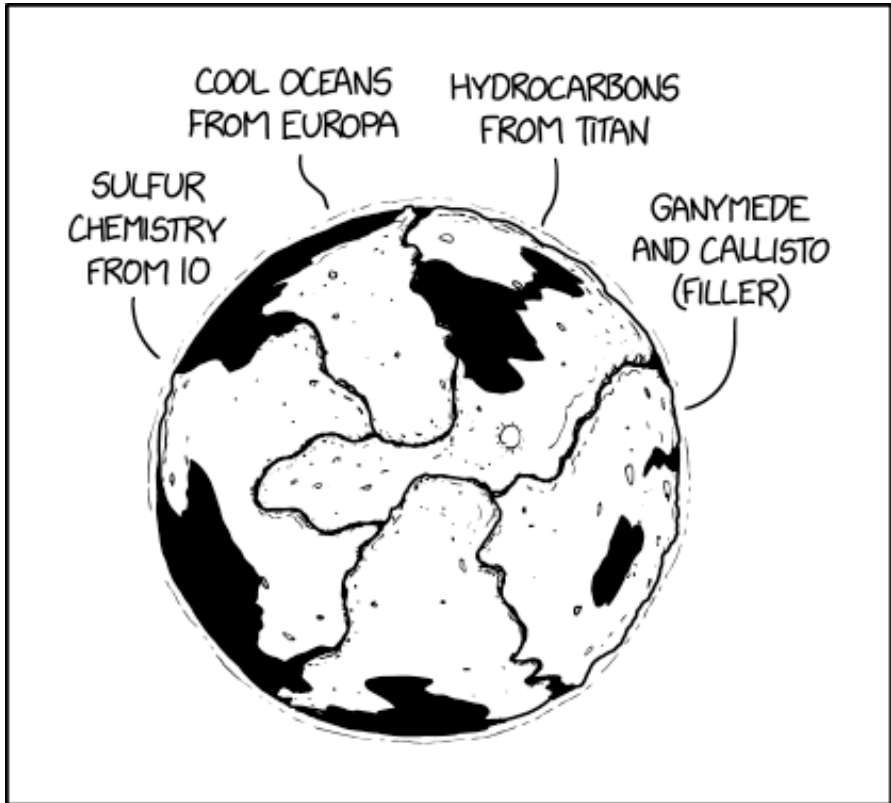
SCIENTISTS NOW THINK THE FIVE BIGGEST OUTER SOLAR
SYSTEM MOONS ARE ACTUALLY JUST INGREDIENTS;
WE'RE SUPPOSED TO COMBINE THEM TO CREATE A SINGLE
MARS-SIZED PLANET THAT'S COOLER THAN ANY OF THEM.

Add main-belt asteroids to taste.

Explanation

This comic jokes that it is possible, and perhaps intended, to use the five largest moons in the outer solar system (the Galilean moons and Titan) as ingredients to create a "better" planet that has the "coolest" features. Apparently, though, Randall couldn't actually think of anything cool that Ganymede and Callisto would contribute, so these have just been used as 'filler'. (However, Ganymede does have a magnetic field, which is kind of cool....)

Note that Earth's moon is the fifth-largest moon of the solar system overall (Europa is the sixth), so it would have been included had "outer solar system" not been specified.

If all of these moons were lumped together, the total volume of "Randall's planet" would be 248 billion km3, assuming no further material compaction, with a surface area of 191 million km2. This is about 1½ times the volume of Mars, or roughly a 15% larger diameter. The combined mass, however, would be smaller than that of Mars.

The title text takes it further, treating asteroids as a "to-taste" ingredient in this "recipe", more like preparing a food dish rather than making a new Mars-sized planet.

There are a number of science fiction works that posit that advanced alien civilizations left puzzles in the solar

system for future humans to solve. Examples for this trope are Pushing Ice by Alastair Reynolds and Rogue Moon by Algis Budrys. The Arthur C. Clarke stories The Sentinel and Encounter in the Dawn (and the more well-known 2001: A Space Odyssey book and film treatments that they later helped inspire) each feature various partial treatments of this concept. Caltech Professor David Goodstein also speculated in The Mechanical Universe the possibility that Saturn is an alien message system.

#2994: Númenor Margaritaville

October 04, 2024
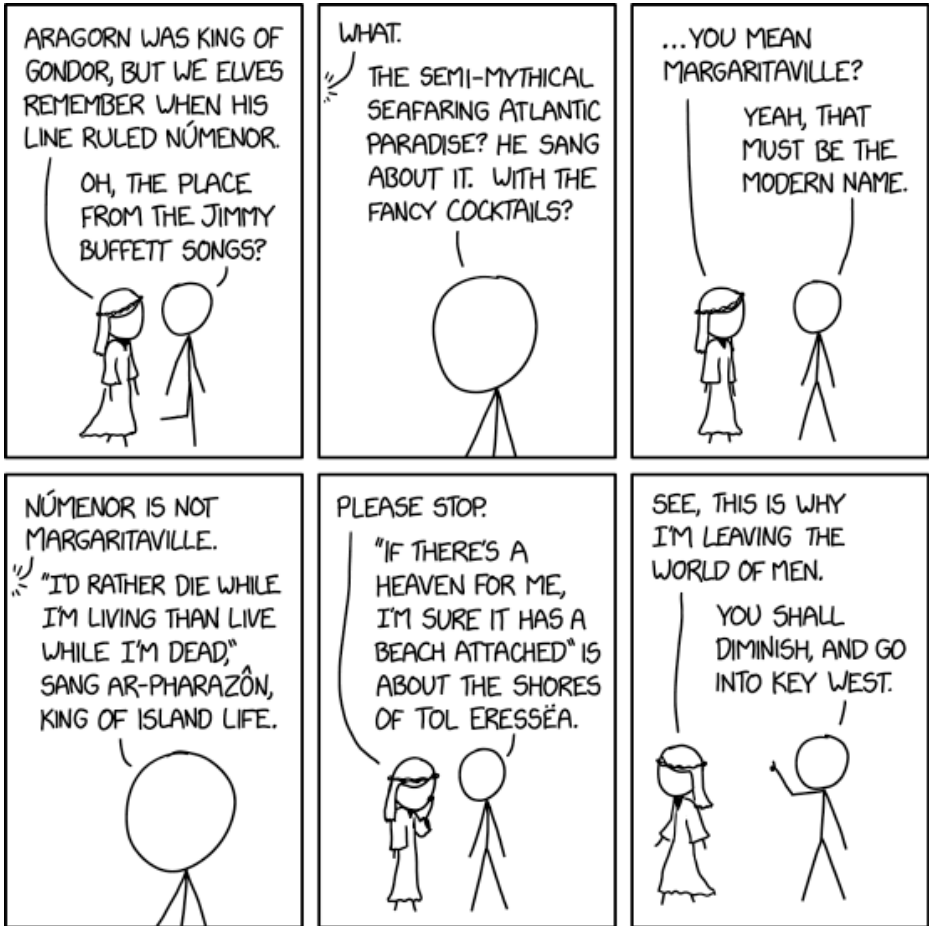
I see white shores, and beyond it, a far green country under a tequila sunrise.

Explanation

Cueball is conflating J.R.R. Tolkien's fictional island "Númenor" with the beach resort in Jimmy Buffett's "Margaritaville". The Elf who is telling him about Númenor, and Aragorn's link to it, becomes progressively more upset, and for cause.

Aragorn, more precisely Aragorn II, is the principal Mannish character of Tolkien's The Lord of the Rings. He is crowned High King of Gondor and Arnor at the end of the saga. He is descended from Elros Tar-Minyatur, first king of Númenor and brother of Elrond.

"I'd rather die while I'm living than live while I'm dead" is a line from Buffett's song "Growing Older But Not Up", from his 1981 album Coconut Telegraph. Ar-Pharazôn, the twenty-fifth, and last, king of Númenor, sought to conquer the Undying Lands, resolving to win eternal life, or die in the attempt. He was therefore responsible for the destruction of Númenor, the removal of the Undying Lands from Arda, and the transformation of Arda into a sphere.

"If there's a heaven for me, I'm sure it has a beach attached" is a quote from the chapter "A Caribbean Soul" of Buffett's autobiography A Pirate Looks at Fifty. Tol Eressëa is an island off the coast of Aman, the continent on which the Valar (divine angelic spirits) live. Aman is thought to have been inspired by the concept of a
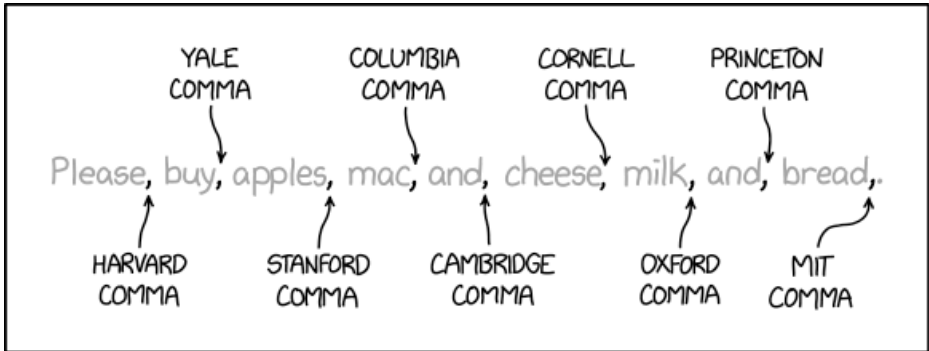
paradise out of time.

Cueball's last line alludes to a statement made by Galadriel in The Fellowship of the Ring, in the chapter "The Mirror of Galadriel": "I will diminish, and go into the West, and remain Galadriel." Cueball's altered version of the statement refers to Key West, Florida, a city closely associated with Buffett, where he lived for many years, recorded albums, and established the first restaurant in his Margaritaville chain.

The title text alludes to a line from Book VI, Chapter 9: The Grey Havens in The Return of the King. "And then it seemed to him [Frodo] that as in his dream in the house of Bombadil, the grey rain-curtain turned all to silver glass and was rolled back, and he beheld white shores and beyond them a far green country under a swift sunrise." The modified line makes a reference to the Tequila sunrise cocktail - and, perhaps, to the song by the Eagles, which is thematically similar to "Margaritaville".

Tolkien's legendarium is frequently alluded to in xkcd.

#2995: University Commas

October 07, 2024

YALE COMMA   COLUMBIA COMMA   CORNELL COMMA   PRINCETON COMMA

Please, buy, apples, mac, and, cheese, milk, and, bread,.

HARVARD COMMA   STANFORD COMMA   CAMBRIDGE COMMA   OXFORD COMMA   MIT COMMA

THE OXFORD ONE IS THE MOST FAMOUS, BUT MANY
MAJOR UNIVERSITIES HAVE THEIR OWN COMMA.

The distinctive 'UCLA comma' and 'Michigan comma' are a
long string of commas at the start and end of the
sentence respectively.

Explanation

The use of commas in the English language is famously disputed, most relevantly among publishers and academics. This comic imagines that all possible (and some improbable) comma positions in an example sentence are associated with different universities. This applies to commas which should always be present in a list, optional commas (regardless of whether they have anything to do with a list, such as after the word "please") and blatantly erroneous commas (which should never be present in a sentence, e.g. immediately prior to the full stop/period).

The Oxford comma (a.k.a. serial comma or, despite how this comic represents it, the actual Harvard comma) is a comma between the penultimate item in a list and its conjunction (typically and or or), to echo all the commas (at least one) that act as placeholders for the conjunction in-between all prior members of the list. For instance, you might write "red, white, and blue" (with the Oxford comma) or "red, white and blue" (without it). Some style guides, such as The Oxford Style Manual published by Oxford University Press, (unsurprisingly) recommend using it, while other similarly authoritative guides recommend against it. Though even those with either recommendation may suggest its (non-)use in situations where this avoids an ambiguity arising from the normally recommended choice.

One common example showing the need for an Oxford

comma is "To my parents, Ayn Rand, and God". Without the comma (as in: "To my parents, Ayn Rand and God"), it may read that the author's parents are Ayn Rand and God. If such confusion is to be avoided, reordering the list is a common way to avoid ambiguity, for example, "To Ayn Rand, God and my parents" is one such reordering. However, the use of an Oxford comma in this version might imply the deification of Ayn Rand. Conversely, if the sentence was instead to be "To my mother, Ayn Rand, and God", with such a comma, there arises the possibility of an assertion that one's mother is Ayn Rand, whereas "To my mother, Ayn Rand and God" does not let one fall into that trap.

Macaroni and cheese (often shortened to "Mac and cheese" in the US and Canada) should be considered a single item in a list like this. When just two items are joined together, e.g. to name a compound food such as "peanut butter and jelly", "fish and chips" or "steak and eggs", a comma isn't placed before "and". It is in the use of such compounded items, as a singular list item, where some confusion can arise. Alternate forms ("fish'n'chips", "salt-and-pepper", "PB&J") can put emphasis upon the low-level linking of the components, the outer list can be rewritten (e.g. with semicolon separation) or the reader can be left to logically assume where such a commonly encountered pairing is not part of the wider list. A difference in conjunction can also help to clarify, as in "A good choice of breakfast is ham and eggs, sausage and eggs or sausage and beans, but not ham and beans", which is unlikely to be accidentally misunderstood

(including as options such as "sausage + (eggs or additional sausage) + beans" or "sausage + ('non-ham' beans) + further beans").

In the most common interpretation the example sentence reads (with proper punctuation and bracketed Oxford comma): "Please buy apples, mac and cheese, milk[,] and bread."

However, most of the commas are possible punctuation marks in a specific pragmatic reading of the sentence:

Depending upon who you talk to, the two establishments referenced by the title text may not be considered quite as prominent or outstanding as the Ivy League universities, or others mentioned here, hence their relegation to title text punchline. But (actual Ivy Leaguers) Brown University, Dartmouth College and the University of Pennsylvania were not referenced at all, for one reason or another; for example, the very idea of a "Brown comma" might more readily resonate with the concept of the Brown note.

#2996: CIDABM

October 09, 2024

GEOPOLITICAL NEWS: SICILY, SRI LANKA, HAINAN, AND TASMANIA HAVE JOINED TOGETHER TO FORM THE COALITION OF ISLANDS THAT DANGLE AWKWARDLY FROM THE BOTTOM OF A MAINLAND.

There's a heated debate over whether the big island of Tierra del Fuego should qualify for membership.

Explanation

The comic parodies intergovernmental cooperations, such as the G7 "group of seven" (Canada, France, Germany, Italy, Japan, the United Kingdom and the United States) or the BRICS group (originally Brazil, Russia, India and China, with South Africa soon after rounding off the acronym before further nations attained membership). Such treaties, and other more casual associations between nations, can be based upon some close association in geographical, political, cultural and/or economic terms (or even, in some cases, by little more than sharing a common opposition to a different bloc of nations).

The "CIDABM" group, named for the very specific membership criteria, has been formed on a rather more abstract basis than most geographically-focused groupings (e.g. NATO or the Pacific Islands Forum) and (currently) consists of four otherwise disparate islands:

- Sicily is an autonomous region of Italy, which is on the south eastern edge of the Eurasian mainland.

- Sri Lanka is a nation in its own right, south of India, which is on the southern edge of the Eurasian mainland.

- Hainan is a province of China, which is on the south eastern edge of the Eurasian mainland.

- Tasmania is a state of the nation of Australia, south of the eastern side of continental Australia mainland.

These four islands 'dangle below' their mainlands only because of the convention of having north at the top of maps. If the mapmaking convention had instead been to have south at the top, the islands might have been described as floating above their continents. Conversely, Madagascar, Newfoundland or Adelaide Island might have been applicable members of similar 'dangling' alliances where the basic premise might come from one or other different map orientations.

The big island of Tierra del Fuego (Isla Grande de Tierra del Fuego), mentioned in the title text, is off the southern tip of the Chilean mainland (as well as a small bit of Argentina). Unlike the others in the comic, it doesn't prominently 'dangle' south of a mainland: it has narrow channels separating its northern and northwestern sides from the mainland, and other parts of the Tierra del Fuego archipelago surround its southwestern side and make it appear well-connected to the mainland. In addition, it isn't a single political entity: the island is split between Chile to the west and Argentina to the east. The 'heated debate' mentioned in the title text may be a play on Tierra del Fuego being Spanish for Land of Fire.

While the banner on stage depicts each of the islands with approximately the same size, Tasmania (68,400 km²) and Sri Lanka (65,600 km²) are much larger than Hainan (35,200 km²) and Sicily (25,800 km²). Isla Grande de Tierra del Fuego is in the middle sizewise (48,000 km²).

Here is a list of island that clearly do not belong to this

club:

- Corsica (8,700 km², south of France's mainland) but clearly not dangling beneath the tip of a land mass like Sicily but on the side of Italy.
- Cyprus (9,300 km², south of Turkey) but also to the west of Syria thus not dangling beneath a land mass.
- Kyushu (36,800 km²) and Shikoku (18,800 km²) that are very close and south of the Japanese mainland of Honshu but this is an island state so island beneath island kind of makes no sense here.
- The same problem with Stewart Island/Rakiura (1,746 km²), which dangles south of the South Island of New Zealand again an island state so island beneath island kind of makes no sense here.
- The Isle of Wight (merely 380 km²) is not really beneath the UK as part of the mainland goes more to the south and again an island state so island beneath island kind of makes no sense here.
- Gotland (3,200 km²) and Long Island (3,600 km²) are even smaller and, like Taiwan (36,200 km²), are not even close to being south of their respective mainlands.
- Cuba (105,800 km²) which "dangles" south of Florida seems to also not quite fit the theme as it is much larger and longer than the part that is "dangles" beneath and thus would not be considered dangling from Florida, rather supporting Florida.
- Sumatra (482,300 km²), is not dangling south of the Malay peninsula as it goes much higher up and is also

much larger than the part of the mainland it should dangle beneath so makes no sense to look as it as dangling.

#2997: Solar Protons

October 11, 2024

If any of you want to meet some cool local oxygen atoms, I can introduce you!

Explanation

This comic is referencing the solar storm that hit the Earth on Thursday night before the comic. A result of the storm was that northern lights were visible across much of the northern United States, including Massachusetts where Randall lives. The northern lights normally occur much farther north, making this a rare and spectacular occurrence. The rare color background of this panel is an illustration of the northern lights.

The solar protons referenced are hydrogen nuclei ejected from the Sun. Since most hydrogen atoms are just a single proton and electron pair, once the electron is removed, the resulting ion is just a proton. These protons, being positively charged, interact with Earth's magnetosphere, and the resulting excitation of atoms in the atmosphere causes them to emit light in the form of aurora. In the northern hemisphere the aurora is called aurora borealis (Latin for "northern dawn") and in the southern hemisphere it is called aurora australis (Latin for "southern dawn").

Note, however, that - contrary to some common misconceptions - auroras are only created indirectly due to the impact of solar particles, and only a small fraction of all auroras are triggered by solar protons from coronal mass ejections. Most auroras are caused by electrons, and these electrons are mostly already trapped over the long term in Earth's magnetosphere (although many of them originated in the solar wind at some point). The

interaction of the solar wind's magnetic field with Earth's magnetosphere can create strong electric fields parallel to the magnetic field lines near the poles, and these electric fields energize the electrons and accelerate them into the atmosphere, where their interactions with oxygen and nitrogen molecules create the emission lines of the aurora. The comic merely implies that there must be solar protons arriving on Earth when there are such impressive northern lights in Beret Guy's home town, which seems likely.[citation needed]

Here, Beret Guy takes on the task of giving the protons a cordial welcome to Earth, where they will spend the foreseeable future. He has set up a sign to welcome them, presumably because he is happy to see the northern lights. His sign claims that they will love being part of the atmosphere, presumably because the protons are interacting with other atoms in the atmosphere if aurora lights are emitted. The sign also invites them to try creating water. Water consists of one oxygen atom and two hydrogen atoms sharing an electron each with the oxygen. Since the solar protons are just hydrogen nuclei, they can form water by interacting with oxygen atoms or hydroxide ions (OH-). Scientists believe that solar wind frequently creates water by interaction of the hydrogen nuclei with oxygen. However, the mechanism proposed involves solar wind first creating hydroxide from compounds in asteroids and space dust, and then another proton joining to make water. As most of the oxygen in Earth's atmosphere consists of O_2 molecules (two bound oxygen atoms), it is not clear if solar protons could create

water in the atmosphere at the same time as the northern lights, as opposed to via various other intermediate atmospheric/geological/biological interactions which might take up hydrogen (ionised or otherwise).

The title text references water formation by saying that Beret Guy can introduce the solar protons/hydrogen nuclei to cool oxygen atoms. In reality hydrogen nuclei from the solar wind do not need an introduction,[citation needed] but instead, due to their great speed, form bonds with oxygen when they impact oxygen or hydroxide.

#2998: Ravioli-Shaped Objects

October 14, 2024
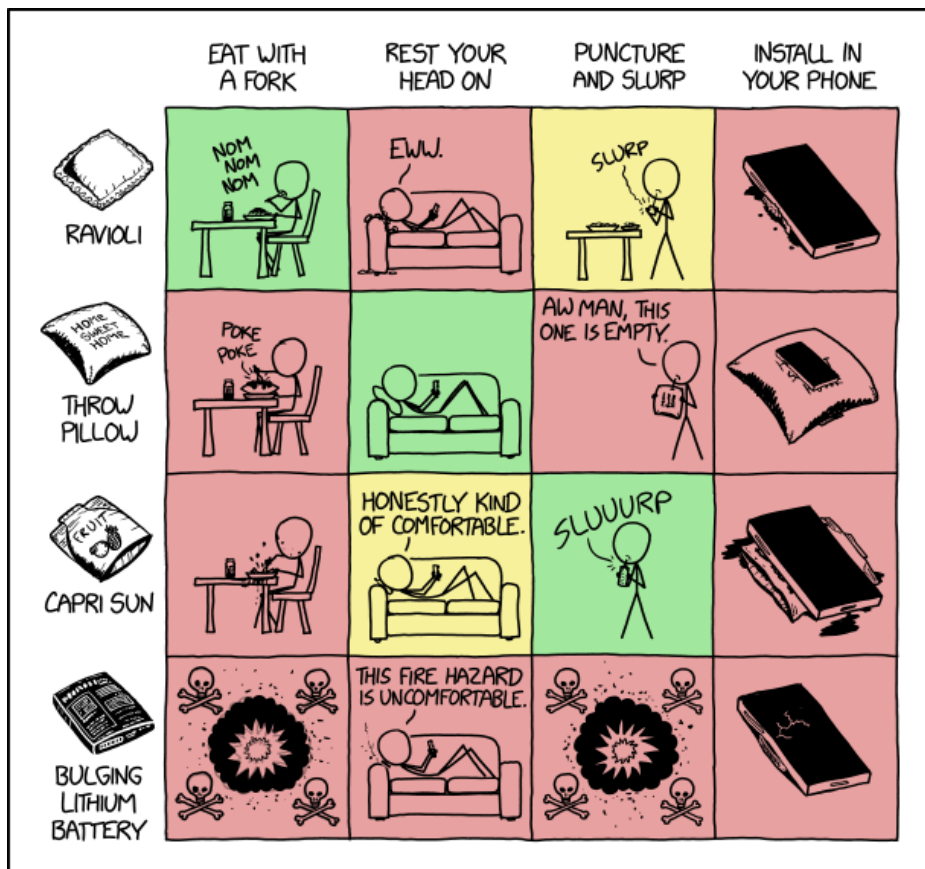
It's a real accomplishment to mess up a ravioli recipe badly enough that the resulting incident touches all four quadrants of the NFPA hazard diamond.

Explanation

Ravioli are a kind of stuffed pasta comprising a filling enveloped in thin pasta dough, commonly square shaped, and serving as the object of this comic's table, which can be seen as a kind of confusion matrix. This comic compares four ravioli-shaped objects (square shaped objects with bulging cross-sections due to their filling) with some common actions associated with them. See the table below.

The title text refers to the NFPA 704 diagram for hazardous materials, a diamond figure put out by the National Fire Protection Association showing four kinds of fire hazards. A raviolo that touched all four quadrants would be a health hazard, fire hazard, and demonstrate (chemical) reactivity, and have some other miscellaneous hazard(s). The NFPA diamond was previously mentioned in 2638: Extended NFPA Hazard Diamond.

Table of ravioli objects[edit]

#2999: Bad Map Projection: The United Stralia

October 16, 2024

This projection distorts both area and direction, but preserves Melbourne.

Explanation

This is the eighth comic in the series of Bad Map Projections displaying Bad Map Projection #102: The United Stralia. It follows 2951: Bad Map Projection: Exterior Kansas (#45), released about three and a half months earlier.

In this addition to the Bad Map Projections series, Randall has blended two different countries — the United States of America and Australia — into one.

As with a number of Bad Map Projections, the primary joke is the naming of this as a "map projection". Its depiction is particularly similar to 2807: Bad Map Projection: ABS(Longitude), in which geography is overlaid upon other geography. It also follows the practice of 2256: Bad Map Projection: South America, in which a general continental shape is forced upon other areas, with the general geographical outline of the 48 contiguous US states being merged with the political boundaries of Australia (with exceptions, most obviously Australia's Bass Strait being retained in lieu of the US's central Florida). At a further level of merging, the US states are repacked as subdivisions within the various Australian ones; as with the likes of 2394: Contiguous 41 States, it also takes some liberties with the relative neighboring positioning of some of these, although not by totally removing any of the actual contiguous United States. Alaska and Hawaii aren't included, likely because the 48 contiguous US states better match the shape and

size of Australia. Australia also has no territories that would make a good match in size or shape for Alaska and Hawaii.

The geographically relative climate of the states of the USA is broadly opposite of Australia's. Australia's north is closest to the equator but the USA's north is farthest from the equator. Thus, if Australia's climate were literally applied to the US, Florida would be relatively cold while Maine would be hot. Likewise, applying USA's climate to Australia would make northern Australia unusually cold and southern Australia relatively hot.

The map pokes fun at superficial and irrelevant similarities between features of the maps of the United States and Australia, such as the shape of the east coasts of New England and the Cape York Peninsula, and the distance to the southern tip of the island of Tasmania and the length of the Florida peninsula. The end result is to illustrate a fanciful place which does not actually exist and thus would have limited worth for navigating either Australia or the USA, although navigation between two listed locations/areas drawn from the same original continent would at least be broadly possible (with the possibility of a few 'surprises' en route). The blending features cities from both countries on the map, e.g., San Francisco and Los Angeles (USA) close to Perth (Australia).

The states and territories of Australia are depicted with black lines/labels, while the states of the United States

and such cities as are taken from either nation are marked with gray. The Australian states are labeled with their full names, but the American states are given only their postal abbreviations. (Mississippi is mislabeled as MI, in addition to Michigan's own correct usage, instead of the official MS.) Western Australia is usually abbreviated to WA, but the convention here leaves that unambiguously assigned to the US state of Washington. Idaho, for some reason, is not labeled at all, and neither is the Australian island state of Tasmania.

The title text makes a joke that this map does not preserve area or direction (typically, a map projection sacrifices one to preserve the other, or both to correctly depict a particular distance metric), but does preserve the city of Melbourne as a feature located on the map, near the actual location of Melbourne, Florida. Note that this is not the correct location of Melbourne, Australia, as it is far too much east in the bad map projection, but there is nothing to stop the shared Melbourne being entirely 'correct' and every other feature being shifted as a 'compromise'. The concept of a point being 'preserved', rather than actual dimensionally-meaningful quantities, is meaningless and just adds to the badness of the projection. There are other city names shared between the US and Australia, but they're not located at any obviously similar geographic locations; e.g., the location of Brisbane in the comic is based on the instance in Queensland, not California (potentially named after the main example) or North Dakota.

This is the second comic in October 2024 in which

Tasmania appears, the first being 2996: CIDABM. Both feature the major island groups in the Bass Strait, in this case perhaps intended as a sort of analogue to the Florida Keys, or else orphaned coastline features across the 'missing' segment of the US peninsula.

Geographical relationships[edit]

From west to east, the Australian states and territories contain the following U.S. states; the positions of Australian cities on the map are also listed:

Western Australia contains the following U.S. states:

• Arizona
• California

  Perth appears on the California coast, about halfway between Los Angeles and San Francisco.

• Colorado
• Idaho
• Montana
• Nevada
• New Mexico
• Oregon
• Utah
• Washington
• Wyoming

Northern Territory contains the following U.S. states:

- Illinois
- Iowa
- Kansas
- Michigan (Upper Peninsula)
- Minnesota

Darwin is positioned in northwestern Minnesota.

- Missouri
- Nebraska
- North Dakota
- South Dakota
- Wisconsin

South Australia contains the following U.S. states:

- Arkansas
- Louisiana

Adelaide is located in the Mississippi River delta region of Louisiana.

- Oklahoma
- Texas

West Texas is now in the Eucla time zone (GMT+8h45), although it is on the wrong side of the bent WA/SA border

Queensland contains the following U.S. states and territories:

- Connecticut

- Delaware

- District of Columbia

- Indiana

- Kentucky

- Maine

- Maryland

- Massachusetts

- Michigan (Lower Peninsula)

- New Hampshire

- New Jersey

- New York

- North Carolina

 Brisbane is located on the coast in southeast North Carolina.

- Ohio

- Pennsylvania

- Rhode Island

- Tennessee

- Vermont

- Virginia

- West Virginia

New South Wales contains the following U.S. states:

- Alabama

- Georgia

Canberra, and presumably the rest of the Australian Capital Territory, is located in southeastern Georgia.

- Mississippi
- South Carolina

Sydney is located along the coast of South Carolina, near the location of Charleston.

Victoria and Tasmania combine to make up the U.S. state of Florida, which is now divided into two non-contiguous parts. As a result Tasmania, which has a history of being omitted from maps of Australia, is displayed but not named. Melbourne is located in the southeast corner of Victorian Florida. Although Tasmania's largest city Hobart is not labeled, it could share the same general location of Miami on the map. Alaska and Hawaii, the two non-contiguous states of the United States, do not appear in the projection. Other major geographic distortions include:

- The U.S. now has two quadripoints, with the intersection of Colorado, Kansas, Oklahoma, and New Mexico joining the existing Four Corners.
- Indiana has a border with Arkansas.
- Alabama and Mississippi have lost Gulf Coast access, as Florida has a border with Louisiana.
- Missouri has a north-south border with Oklahoma.
- Miami is separated from the lower 48 states, as it is now located in the non-contiguous Tasmanian Florida.

#3000: Experimental Astrophysics

October 18, 2024

A THORNE-ŻYTKOW OBJECT IS A HYPOTHESIZED NESTED STAR—A RED GIANT WITH A NEUTRON STAR INSIDE IT.

SO FAR, NO TŻOs HAVE BEEN DEFINITIVELY OBSERVED, BUT YOUR GRANT COULD HELP US CHANGE THAT.
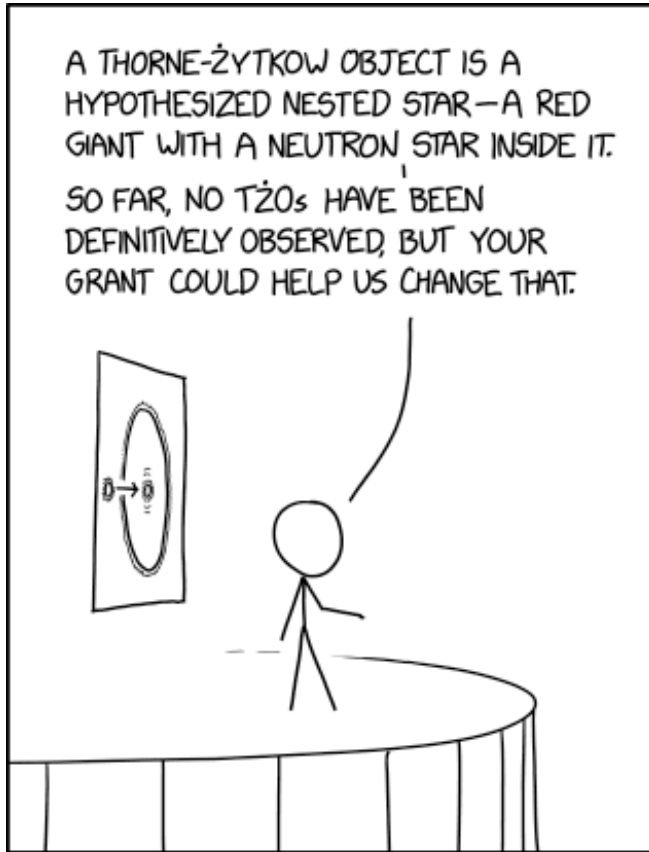
WE'RE STRUGGLING TO GET FUNDING FOR OUR PROJECT TO SLINGSHOT A NEUTRON STAR INTO THE SUN.

Our experiment will be expensive, but we believe it will produce important spin-offs, especially if we manage to hit the sun from the right angle.

Explanation

A Thorne–Żytkow object is an object theorized by astrophysicists Kip Thorne and Anna Żytkow which is a red giant or red supergiant with a neutron star at its core. There have been no confirmed sightings, but HV 2112 and HV 11417, both in the Small Magellanic Cloud, have in the past been considered strong candidates.

Cueball is asking for a grant for funding for research into these theoretical astral bodies, the implication being that they are asking funding for telescope time, or even an entirely new telescope, in order to make such investigations possible. However, the caption reveals that he is asking for something completely different: funding to create the object, with a gravitational slingshot. Normally, astrophysics is an observational discipline, but the title of the comic (made explicit by the caption text) suggests that this is intended to be a 'practical' experiment to induce a TŻO into existence by actually sending a neutron star into our own Sun.

Cueball is complaining that no one is willing to fund this experiment to create the Thorne–Żytkow object for direct observation. Creating it would be impractical, for several reasons. First, you would need to find (or create!) a neutron star and bring it here, which requires amounts of energy, mass, and precision that we have no current possibility of achieving. Secondly, having a neutron star anywhere near the Sun would most likely destroy the solar system, or at least accelerate its transition to a red

giant, which would likely result in Earth being engulfed by it and ruining the weather. The funding body, presumably based on Earth, would probably find the study would not pass an ethics review, and the end result would not generate a favorable environmental impact statement, given the almost inevitable destruction of our planet.

A spin-off usually means something additional that was not originally planned. The title text in this comic is a two-layer joke on the phrase "spin-off", meaning that hitting the Sun off-center (from the right angle) would likely have many unintended consequences, but also cause the Sun to start rotating abnormally, due to the added angular momentum, in the same way as hitting a ball on the side makes it spin. A similar idea (the engulfment of a planet or companion star) has been proposed to explain the apparently anomalous rotation of the red supergiant Betelgeuse.[actual citation needed] "Spin-off" could also refer to material being flung off the Sun due to the impact of the neutron star. If the right material is sent in certain directions, it could have useful, or more likely just 'interesting', properties.

#3001: Temperature Scales

October 21, 2024

TEMPERATURE SCALES

UNIT	WATER FREEZING POINT	WATER BOILING POINT	NOTES	CURSEDNESS
CELSIUS	0	100	USED IN MOST OF THE WORLD	2/10
KELVIN	273.15	373.15	0K IS ABSOLUTE ZERO	2/10
FAHRENHEIT	32	212	OUTDOORS IN MOST PLACES IS BETWEEN 0-100	3/10
RÉAUMUR	0	80	LIKE CELSIUS, BUT WITH 80 INSTEAD OF 100	3/8
RØMER	7.5	60	FAHRENHEIT PRECURSOR WITH SIMILARLY RANDOM DESIGN	4/10
RANKINE	491.7	671.7	FAHRENHEIT, BUT WITH 0°F SET TO ABSOLUTE ZERO	6/10
NEWTON	0	33-ISH	POORLY DEFINED, WITH REFERENCE POINTS LIKE "THE HOTTEST WATER YOU CAN HOLD YOUR HAND IN"	7-ISH/10
WEDGEWOOD	-8	-6.7	INTENDED FOR COMPARING THE MELTING POINTS OF METALS, ALL OF WHICH IT WAS VERY WRONG ABOUT	9/10
GALEN	-4?	4??	RUNS FROM -4 (COLD) TO 4 (HOT). 0 IS "NORMAL"(?)	4/-4
REAL CELSIUS	100	0	IN ANDERS CELSIUS'S ORIGINAL SPECIFICATION, BIGGER NUMBERS ARE *COLDER*; OTHERS LATER FLIPPED IT	10/0
DALTON	0	100	A NONLINEAR SCALE; 0°C AND 100°C ARE 0 AND 100 DALTON, BUT 50°C IS 53.9 DALTON	53.9/50

In my new scale, °X, 0 is Earths' record lowest surface temperature, 50 is the global average, and 100 is the record highest, with a linear scale between each point and adjustment every year as needed.

Explanation

Since the invention of the thermometer, a number of different temperature scales have been proposed. In modern times, most of the world uses the 1745 Celsius scale for everyday temperature measurements. A small number of countries (the USA and its territories, the Bahamas, Belize, the Cayman Islands, Liberia, and Palau) retain the imperial system (or the related US customary system), which uses the 1724 Fahrenheit scale. The other widely used temperature scale is the 1848 Kelvin scale, which uses the same gradations as degrees Celsius but is rooted at absolute zero, making it both useful in scientific calculations and easy to convert to and from Celsius (which, along with degrees Fahrenheit, is now defined relative to kelvins.) The Kelvin scale has been part of the widely adopted official metric system since 1954. Even in countries that use Fahrenheit, scientific measurements are usually made in degrees Celsius or kelvins.

The comic compares these scales, and a number of others, on Randall's scale of "cursedness." The joke is highlighting how different the temperature scales are, and how impractical most of them are. All of the listed scales (except Randall's new °X scale defined in the title text) are real, but most are obsolete. 1643: Degrees provides helpful tips for choosing whether to use Celsius or Fahrenheit. See also 1923: Felsius.

Examples[edit]

Some temperatures in the above scales:

Here are the conversion formulas for the Felsius scale:

#3002: RNAWorld

October 23, 2024

OKAY, KIDS, NOW THAT ARIEL IS DONE COLLECTING NUCLEOTIDES FOR RATATOUILLE'S PRIMORDIAL SOUP, LET'S GO WATCH ELSA INITIATE RUNAWAY RIBOZYME SYNTHESIS!

DISNEY'S RNAWORLD

Disney lore: Canonically, because of how Elsa's abiogenesis powers work, Olaf is an RNA-only organism.

Explanation

This comic conflates biology and Disney World. Disney World is one of a franchise of theme parks with attractions based on various Disney movies, while the RNA world hypothesis is a proposed origin of life, in which RNA acts both as the genetic material and the enzymatic machinery needed to copy it.

Ariel is the titular character from The Little Mermaid. In the film she likes to collect human artifacts; the comic replaces this with collecting nucleotides, the basic building blocks of DNA and RNA.

Ratatouille is a film about a French rat named Remy (not "Ratatouille"; see here) who dreams of becoming a gourmet chef. The comic conflates the soup that a chef might create for patrons to eat with "primordial soup", the environment that's believed to have existed on the early Earth when the processes of life began.

Elsa is one of the lead characters from the Frozen movies. In the film she has the magical ability to control ice and snow, and she used this power to make the snowman Olaf come to life. The comic equates this with the original emergence of life on Earth, or life from non-life, through ribozyme synthesis. Ribozymes are RNA molecules that, similarly to enzymes made of protein, catalyze biochemical reactions, such as the splicing of RNA during gene expression.

The title text continues this by saying that since Elsa's ability is based on ribozymes, Olaf's machinery of life must be based only on RNA, not DNA. This fits in with the theme of RNA World. Olaf generally appears to be (by mass) mostly just snow but, in common with various ideas about the makeup of cometary ice (and the role played by them in 'seeding' the young Earth with organic molecules), might well be thoroughly imbued with carbon-rich compounds other than those inherent in his carrot nose, coal buttons, and basic twig/stick elements. "Canonically" refers to fictional canon (in this case Disney fiction), "the body of works taking place in a particular fictional world that are widely considered to be official or authoritative."

RNA has also been mentioned in 2425: mRNA Vaccine and 3056: RNA.

#3003: Sandwich Helix

October 25, 2024
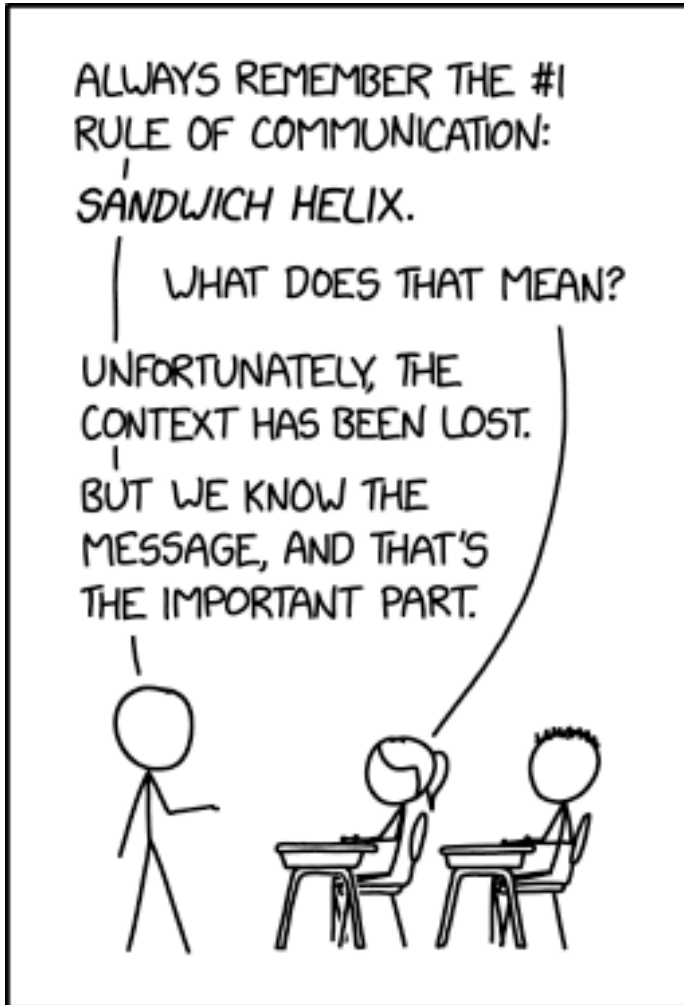
The number one rule of string manipulation is that you™ve got to specify your encodings.

Explanation

This comic details an important issue in communication: even if the content of your message goes through, there might be important context that is necessary to correctly interpret it.

Communication is a way to convey ideas, and Cueball is explaining a concept of communication he calls a "Sandwich Helix". However, when pressed on what that is, he says nobody knows — indicating that, over the years, communication has failed to retain the meaning of this supposedly very important concept. The humor is that if this truly was the #1 rule of communication, communication should have been able to retain its meaning. On the basis that the number #1 rule about communication would probably be the most important rule, it might even be construed to be the rule about properly communicating all context (by some apparent analogy), which would be irony — but only if anyone still understood it.

The comic also displays the difference between meaning and message. Cueball is parroting a message (possibly a cliche repeated by self-help authors and influencers), even though the meaning is lost.

The fictitious "Sandwich Helix" plays on another concept in communication, the "Compliment Sandwich" (a.k.a. "Shit Sandwich"), wherein a statement of criticism is sandwiched between two complimentary
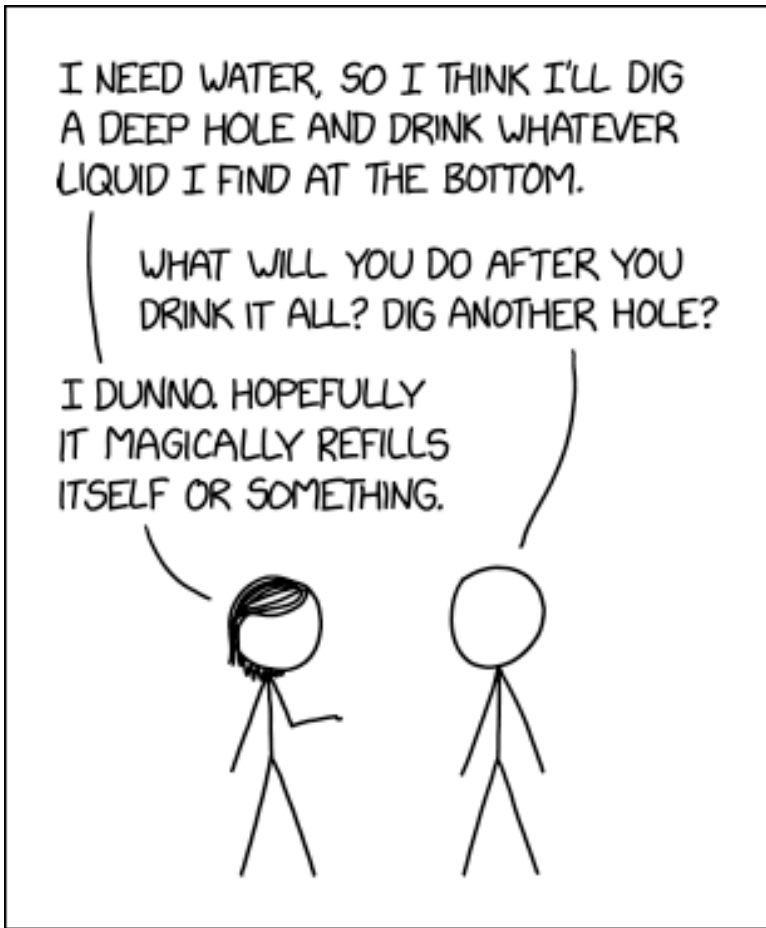
statements in order to make the negative statement easier to accept. The difference is that the Compliment Sandwich is a communication technique which is well known and whose meaning has not been lost (though it is currently disputed whether the technique is effective or whether it even might accomplish the inverse of its goals). A possible inspiration for the "helix" part is the Helical Model of Communication. The creator of the model, Frank Dance, emphasised the role of communication problems. He shows communication as a dynamic and non-linear process.

The title text contains several odd-looking characters that seem random (but are actually meaningful, to those familiar with them) where an apostrophe should be, as an example of a string that did NOT have its encoding handled properly. It is an example of Mojibake. Some special characters and symbols require a special encoding (such as UTF-8, Windows-1252, Shift-JIS, etc) in order to be stored and displayed properly, and are encoded using the equivalent of multiple characters. If the code to display the text doesn't understand what encoding was used and assumes a different/lesser level of encoding, you can get "garbage" similar to what is in the title text. In this case, the original character was ', a "smart apostrophe" which, when encoded in UTF-8 and decoded in Windows-1252, becomes â€™. Similar garbage is seen in the title text of 1683: Digital Data. The apostrophe angled to the right, as opposed to the straight apostrophe normally typed on standard keyboards, is often intended to pair with a leftwards-angled one as marks at either end

of some quoted text, `smartly´ applied by some word processing software by way of an autocorrection of what was typed - though not always when actually wanted, or correctly applied even when it might be.

#3004: Wells

October 28, 2024

I NEED WATER, SO I THINK I'LL DIG A DEEP HOLE AND DRINK WHATEVER LIQUID I FIND AT THE BOTTOM.

WHAT WILL YOU DO AFTER YOU DRINK IT ALL? DIG ANOTHER HOLE?

I DUNNO. HOPEFULLY IT MAGICALLY REFILLS ITSELF OR SOMETHING.

IT'S RIDICULOUS THAT WELLS WORK.

You do have to be careful, though--sometimes, instead of water, you hit this free fuel that you can sell for a lot of money instead.

Explanation

Water is essential to life,[citation needed] and humans have long sought out places to get it. Freshwater surface sources like rivers and lakes most obviously dictate where people live, but are subject to changes of quantity and quality (e.g. the seasons/weather and what other people are doing with(/in) the water, upstream). Water can also be present beneath the surface in aquifers, gradually having soaked through into various soil and/or rock layers, and may emerge (far more reliably and usably) from handy seeps and springs where the local ground topology is favorable. But geology and geography don't coincide so usefully everywhere that someone requires water.

Many modern countries (and a number of historic ones) will have at least some ability to pipe water from areas of high availability (e.g. from areas with reservoirs, natural or constructed) to other places of higher consumption (towns and cities), but not everyone will have piped water and may find it better to rely upon a well, a hole dug into the ground, deep enough to reach the local water to lift or pump out as needed. A borehole is similar, but may even puncture impermeable bedrock to access water held (under significant pressure) in rock layers below.

This comic pokes fun of the seemingly improbable characteristics of wells and boreholes; talking about how water "randomly" forms below the surface of the ground

and how they "magically" refill themselves. It also pokes fun at how unrealistic it seems for people to have come up with the concept of wells in the first place; people would have had to dig a hole and hope that water appears.

In reality the complex systems of the water cycle dictate the formation of the underground 'pools' that the wells take from and the seeps of underground water that supply them, meaning that it's not really so surprising (nor necessarily quite as simple as it sounds) to get your water from beneath the ground, and is a process not restricted to humans. This theme of things that seem like they shouldn't work, but do, has also been used in 2540: TTSLTSWBD, 2115: Plutonium, and 2775: Siphon, among others.

The title text points out that in some cases, people intending to drill water wells instead found oil beds. Oil is a very valuable energy source, so they became very wealthy as a result. This is the source of the idiom "struck oil" to mean receiving a windfall as a result of a lucky occurrence. But you have to be careful — if you blindly "drink whatever you find at the bottom", as Megan says, you'll get very sick if it's oil rather than water. Oil tends to be buried much deeper than water, but each has its own (different) prerequisites that don't make it equally likely to get either (or both) at any given spot. A prior comic made some related points about ground-hydrology.

This comic bears similarity to a Calvin and Hobbes

comic from 1993, one Randall may have been aware of, that points out properties of a common drink that can appear disgusting when the underpinnings are known.

#3005: Disposal

October 30, 2024
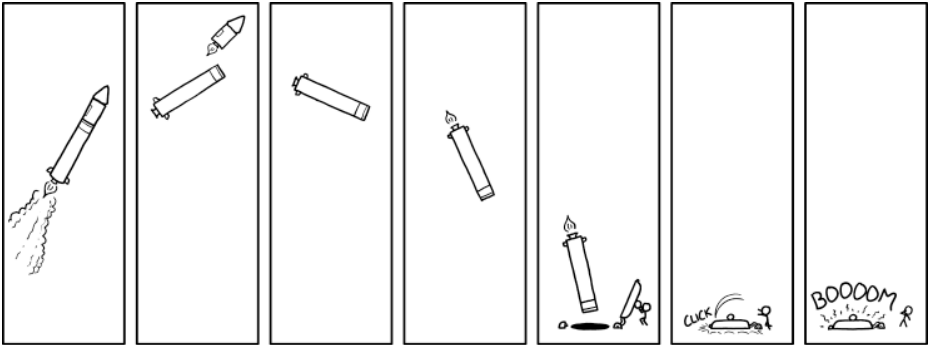
OUR ROCKETS WERE GOOD AT STEERING, BUT WE COULDN'T GET THEM TO LAND WITHOUT EXPLODING, SO WE JUST DUG A ROCKET DISPOSAL HOLE.

We were disappointed that the rocket didn't make a THOOOONK noise when it went into the tube, but we're setting up big loudspeakers for future launches to add the sound effect.

Explanation

This comic came out a couple of weeks after the successful first attempt to 'catch' a rocket during Starship flight test 5, based upon SpaceX having an extensive history of bringing rocket stages back to Earth in a controlled manner. Whereas the traditional approach was for such rocketry to allow most of the initial launch-vehicle to be a single-use stage that was effectively destroyed once it had fulfiled its purpose, it has become a developmental aim across much of the commercial side of the industry to introduce as much reusability as possible in the mission hardware to potentially save costs and construction time.

In order to accomplish a successful recovery, expended stages have been given unprecedented ability to control their fall back to the ground, often in a manner that allows them to propulsively halt their descent directly over a prepared landing pad (on land or sea) and settle down softly enough on landing gear to be refurbished and reused (sometimes for more than twenty subsequent missions). For the recent Starship test, the one (and, as of this comic, only) attempt to recover its Super Heavy Booster involved being precisely guided to be caught by the original launch tower; though it is never expected to refly, as a test prototype, it survived the whole process. This is in contrast with plenty of examples, where the landings (or their aftermath) were not quite so successful.

Though SpaceX is the current leader in such an

accomplishments, there are other companies who are various degrees along a similar developmental route. Randall claims that he has an organisation that is amongst them, and has achieved the non-trivial feat of being able to direct the discarded rocket stage very precisely, yet without that extra bit of ability to ensure that it doesn't then subsequently explode. The team has therefore decided to exploit their achievement (to precisely control the rocket) to send it 'safely' into a hole that (barely larger than the rocket's cross-section, and with a sturdy lid directly manhandled by a Cueball employee) allows it to rapidly disassemble in a planned and 'safe' manner. Of course, as a 'compromise', it does not achieve the original aims of recoverability and reusability, yet it also is intrinsically far more complicated than the default option of just letting the hardware generally fall to destruction somewhere in a handy 'empty' down-range area that shouldn't inconvenience anybody.

With the comic depicting the 'disposed' stage as powering downwards, this might explain their lack of success in perfecting any form of intact recovery, as practical examples of this technology tend to spin the craft around to make use of the main thruster(s) for a retrorocket-assisted landing, or at least don't try to counteract the passive deceleration provided by parachutes or other purposeful aerodynamic drag, in order to touch the ground at a survivable velocity.
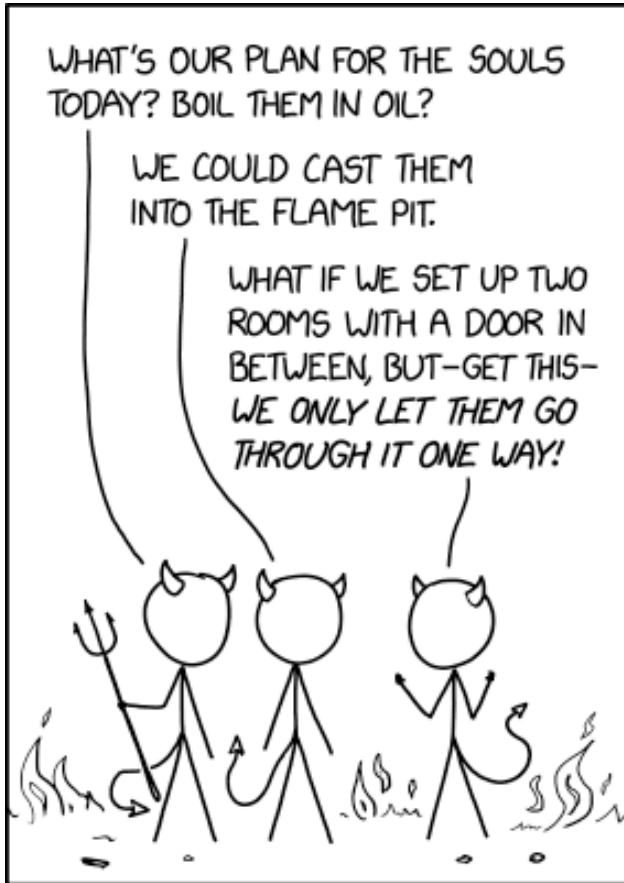
An explosion in a sealed container is potentially much more dangerous than an explosion in the open,

depending on the strength of the container. If the container is strong enough to hold the pressure from the explosion, that pressure could be released in a controlled fashion, safely. But if the container is too weak, it could suffer a catastrophic failure, sending shards of its walls and anything around it flying outwards at high speed. Even if the container is initially strong enough, it could be weakened by repeated explosions, and fail at a random time in the future. As the 'container' is mostly a hole dug into the ground, of indeterminate depth, it might be considered fairly robust in itself, especially if given a reinforced lining. However, this then risks forcing the majority of the resulting explosion up into the lid, which looks strong and heavy yet is closed at least partly by the effort of just one person. It also risks that worker being right next to the track of the descending rocket stage, where they would be at risk of experiencing all kinds of secondary damage, if not being directly in the explosion if they get the timing of the lid-closure wrong. An actual attempt to put a lid on an underground explosion succeeded only in blowing the lid off at such velocity that it was never found.

The title seems to refer to the sound effects of dragging an element into the trash on computers. Or, alternatively, the sound of a canister being sucked into a pneumatic tube. This is perhaps a reference to Tesla vehicles being quiet and having "vroom" noises pumped into the cabin to satisfy customers.

#3006: Demons

November 01, 2024

WHAT'S OUR PLAN FOR THE SOULS TODAY? BOIL THEM IN OIL?

WE COULD CAST THEM INTO THE FLAME PIT.

WHAT IF WE SET UP TWO ROOMS WITH A DOOR IN BETWEEN, BUT—GET THIS— *WE ONLY LET THEM GO THROUGH IT ONE WAY!*

MAXWELL'S DEMON HAD TROUBLE FITTING IN WITH THE OTHERS.

Though they do appreciate how much he improved the heating system for the flame pit.

Explanation

Maxwell's demon is a thought experiment devised by James Clerk Maxwell that appears to refute the second law of thermodynamics, which roughly says that heat always flows from hotter regions to colder. In the thought experiment, two chambers, both containing a gas at the same temperature, have a door between them. A being (later called a demon by Lord Kelvin) lets only fast-moving gas molecules move from the first chamber to the second, and only slow-moving ones move from the second chamber to the first. The second chamber's gas gradually warms as the average speed of its molecules increases, and the first chamber's gas likewise cools, apparently contradicting the second law. However, the actions of such a demon would use up at least the amount of energy that could later be extracted from having a gas separated into hot and cold parts, so such a demon could not gain energy and Maxwell's demon does not break the second law of thermodynamics. The second law of thermodynamics is a fairly common theme in xkcd, last being mentioned in 2848: Breaker Box.

This demon behaves very differently from mythological demons, which exist in the afterlife (usually some form of hell) and punish evil humans after death by causing them great suffering (for example, by boiling them in oil or casting them into flame pits). Randall jokes that if Maxwell's demon were to encounter more stereotypical mythological ones, he would probably not fit in very well because of his very different approach, proposing

treating humans like the particles of the thought experiment. While a few physics-savvy humans might feel offended by such treatment, real suffering could be caused by the anxiety of knowing that, once you choose to cross the door, you are not allowed to return for all eternity.
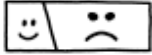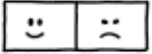
The scientist Maxwell challenged traditional notions about physical phenomena by providing modern statistical explanations of "large-scale effects" such as temperature changes and modern infinitesimal explanations of "distant effects" such as electromagnetic forces. In a similar vein, Maxwell's demon in the comic challenges the mythological demons' traditional notion of torture by proposing modern psychological torture.

The title text continues the joke by suggesting that while Maxwell's demon's idea for torturing the souls of the damned might seem whimsical to the other demons, it could still be used to heat the flame pits better. The other demons' appreciation of this technical improvement mirrors real-life situations where kids that "have trouble fitting in with the others" due to their unusual ideas for games and atypical interests (e.g., in thermodynamics) occasionally earn some appreciation when their cleverness is found to be useful.

This comic was published on 1 November, 2024, the day after Halloween, around the time when many contemporary comic strips have demonic, supernatural or other spooky themes, as well as 4 days before the anniversary of Maxwell's passing (5th of November).

#3007: Probabilistic Uncertainty

November 04, 2024

COPING WITH PROBABILISTIC UNCERTAINTY

SCENARIO	HOW TO THINK ABOUT IT IN AN EMOTIONALLY HEALTHY WAY
GOOD OUTCOME MORE LIKELY	RECOGNIZE THAT THE BAD OUTCOME IS POSSIBLE, BUT BE REASSURED THAT THE ODDS ARE IN YOUR FAVOR
BAD OUTCOME MORE LIKELY	PREPARE FOR THE BAD OUTCOME WHILE REMEMBERING THAT THE FUTURE ISN'T CERTAIN AND HOPE IS JUSTIFIED
PRECISELY 50/50	????? N/A ????

"One popular strategy is to enter an emotional spiral. Could that be the right approach? We contacted several researchers who are experts in emotional spirals to ask them, but none of them were in a state to speak with us."

Explanation

This comic is about the difficulty of dealing psychologically with 50/50 odds, and is likely inspired by the 2024 United States presidential election, as this comic was released the day prior. The odds of the election as reported by many media sources were close to 50/50, where the pre-election polls showed roughly a 50/50 chance of either Kamala Harris or Donald Trump being elected. It seems more and more people suffer from pre-election anxiety and the uncertainty of the results doesn't help.

This 50/50 scenario is the third scenario shown in the comic.

Further, with regards to N/A - the odds of "precisely" 50/50 are probabilistically zero, unless the event under consideration is something relatively trivial such as a coinflip or die roll (and even with those it is extremely unlikely the coins or dice are perfectly "fair"). Any scenario that involves social sciences, such as an election (or even a single relationship) will never be precisely 50/50 (or, indeed, *any* discrete value).

The title text is a joke making use of ambiguous wording: "researchers who are experts in emotional spirals" could either refer to researchers who study emotional spirals, or researchers who are undergoing emotional spirals themselves. Evidently, all the researchers "we" contacted were the latter, and thus unable to advise the comic.

#3008: Proterozoic Rocks

November 06, 2024

Panel 1:

I LOVE BEING NEAR PROTEROZOIC ROCKS.

THESE ONES ARE 1.1 BILLION YEARS OLD.

THAT'S SO, *SO* OLD.

Panel 2:

EYES EVOLVED HALF A BILLION YEARS AGO. THE FIRST TIME A ROCK WAS EVER LOOKED AT, THESE ROCKS WERE ALREADY 500 MILLION YEARS OLD.

Panel 3:

PEOPLE SAY GEOLOGIC TIME MAKES THEM FEEL SMALL. BUT WHEN I TOUCH THIS ROCK, IT'S LIKE I'M A PART OF IT, SPANNING A VAST ABYSS OF TIME THAT STRETCHES BACK AS FAR AS THE EYE CAN SEE.

Panel 4:

AND THEN 500 MILLION YEARS FARTHER.

These rocks are from a time before eyes, brains, and bones, pieces of a land warmed by an unseen sun.

Explanation

Proterozoic eon rocks such as the 1.1 billion-year-old rocks in the comic were formed 2500 to 538.8 million years ago, some of them surviving tectonic movements until today. Proterozoic rocks which were formed from sediment at the bottom of an inland sea such as the former Western Interior Seaway would be in North America today.

The first animal eyes are believed to have developed on trilobites half a billion years ago, around the transition between the proterozoic and phanerozoic eons at the start of the Cambrian period. This transition began a great proliferation of biological diversity known as the Cambrian explosion.

Cueball talks about feeling a connection to the rock, which spans "a vast abyss of time that stretches back as far as the eye can see." This could be interpreted as expressing the need to connect to something that exists vastly beyond the current turbulent era, to put it into perspective and to find strength in knowing that nature transcends human troubles. The title text extends this theme.

The distant past, before the emergence of complex eye-bearing life, is illustrated by the final panel in black. This indicates that Randall is showing what is perceived rather than what was physically present, as light existed and would have made the Earth's surface visible, had

there been eyes to see it. The dark far past may also be an analogy for the darkened far future, as there may be no human life on Earth in around 250 million years. This timeline is far beyond the immediate cares of the current world, applying further perspective to present worldviews.

2013: Rock also compares the age of rocks to milestones in the development of life.

#3009: Number Shortage
November 08, 2024

THE MATH DEPARTMENT NUMBER SHORTAGE IS GETTING WORSE. WE HAVE ONLY 15 2s AND 12 3s LEFT.

NO, WAIT, 13 2s AND 10 3s.

NO, WAIT...
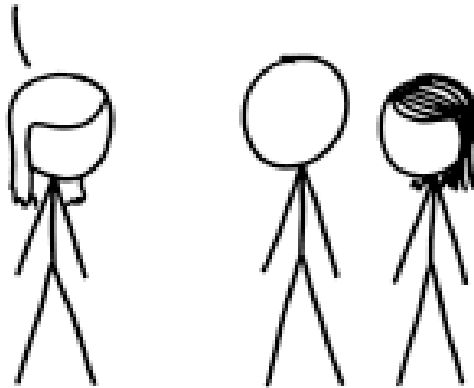
"10 minutes ago we were down to only 2 0s!" "How many do we have now?" "I ... don't know!!"

Explanation

This comic presents a situation where the ability to use numbers is a limited resource. Even quantifying how many numbers are left uses up some of those numbers when stating the results.

In real life, being able to write or say digits is not a limited resource.[citation needed] However, the comic does parallel many educational video games for young children where numbers and mathematical concepts are treated as living people or factory goods, in order to give some sort of story or context to the math-related activities. In addition, the plight faced by the shortage resembles the look-and-say sequence where trying to quantify the list changes it, requiring it to be quantified again (which changes it again, and so on).

The comic conflates numbers with decimal digits. So when Blondie says "15 2s and 12 3s", that uses up two 2s (one in "2s" and one in "12") and one 3 (in "3s"). She adjusts the counts as she's speaking, so when she says "13 2s", that uses up another 3, leaving only 10 3s as she's completing the sentence.

In the title text, she uses the last two 0s when saying that they had two 0s left, so now they have no more 0s. But she can't use the number 0 to describe this situation because they're now out of them.

Blondie could have taken a different approach by saying

"14 2s and 11 3s", which would be accurate once it has been said.

Jokes with a similar theme been made about letters, such as shortages of vowels (and later consonants) in The Onion's "Clinton Deploys Vowels to Bosnia".

Continuation[edit]

A continuation of the pattern would go:

- "We have only 15 2s and 12 3s left."
- "No, wait, 13 2s and 10 3s."
- "No, wait, 12 2s and 9 3s."
- "No, wait, 10 2s and 8 3s."
- "No, wait, 9 2s and 7 3s."
- "No, wait, 8 2s and 6 3s."
- "No, wait, 7 2s and 5 3s."
- "No, wait, 6 2s and 4 3s."
- "No, wait, 5 2s and 3 3s."
- "No, wait, 4 2s and 1 3."
- "No, wait..."
- "How many more do we have?"
- "I...don't know..."

At that point, having used up the last 3 at the end of the previous line, Blondie would lack the necessary 3s to articulate that there are "3 2s and 0 3s."

#3010: Geometriphylogenetics

November 11, 2024
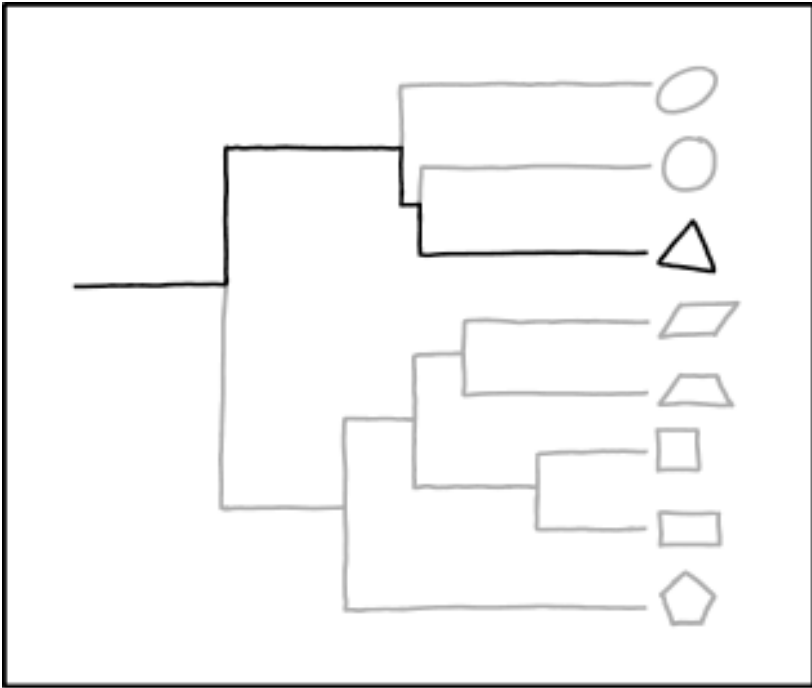
THE PHYLOGENETIC REVOLUTION CONTINUES:

TRIANGLES WERE LONG BELIEVED TO BE RELATED TO SQUARES, BUT GENETIC ANALYSIS PROVES THAT THEY ARE ACTUALLY VERY POINTY CIRCLES.

There's a maximum likelihood that I'm doing phylogenetics wrong.

Explanation

Phylogenetics refers to the practice of examining relationships among things that follow the principle of "descent with modification of progeny". In the course of descent with modification, one thing may give rise to two (the progeny), different modifications happen to each, and those modifications become established. Iterated "splits" over time yield a tree of objects; it is the purpose of phylogenetics to recover ("reconstruct") these trees, and use the information gained to inform study of the things contained. Phylogenetics has been most commonly applied to the classification/taxonomy of biological species and investigations of their evolutionary history, but it has also been used to examine the evolution of genes and biosynthetic pathways. Similar conceptual approaches have been used in the study of human languages and their evolution.

Data for phylogenetic analyses may come from any attributes ("characters") of the things being examined. Rigorous techniques for these analyses became available starting in the 1950s, and these replaced earlier methods based largely on the individual judgement of experts. In phylogenetic studies of organisms, their DNA is far and away the most data-dense source of information, and consequently, most present-day investigations are based on analyses of selected genes and, increasingly, whole genomes. Thanks to the advent of more robust datasets, and more robust methods of data analysis, it is now commonplace for studies, especially on relatively

understudied creatures, to reconstruct an evolutionary history (a phylogeny) that is radically different from what had previously been assumed. This is the "phylogenetic revolution" referred to in the caption. One example is the genus Hippopotamus, which had been considered a relative of pigs, which the animals somewhat resemble, until modern data and methods revealed it to be more closely related to whales, despite the animals being very different physically (hippos spend time in water, but can't swim).

This comic presents a tree, which resembles and purports to be a phylogenetic tree, in which the endpoints ("terminal taxa") are geometric shapes. This has been given the name "geometriphylogenetics" — a portmanteau of "geometry" and "phylogenetics". The claim is that triangles have been moved from the lower part of the tree (where they would be closely related to squares, rectangles, pentangles, and the like) to the upper part (placing them closer to circles and ellipses). This is a riff on the findings, and even the wording, of authentic phylogenetic research papers that report "revolutionary" results. The absurdity, and the joke, is that geometries do not change over time. Human understanding might change, but triangles and circles and rectangles themselves did not evolve or descend from ancestors, they are not progeny of some other geometries of ages past, and therefore phylogenetic principles and techniques don't apply to their study. Moreover, geometries do not contain DNA,[citation needed] so genetic analysis, even if it was ever relevant, is impossible.

The title text alludes to maximum likelihood, one of the most robust, and most frequently used, methodologies for phylogenetic analysis. The method builds a number of trees from the data, assigns to each a probability that it conforms to a pre-selected model of evolution, and then selects the tree that has the highest (maximum) likelihood of conformity to the model. In this case, though, the statement "There's a [high probability] that I'm doing phylogenetics wrong" doesn't just have the maximum probability of the available options; it has the maximum possible probability of 1, because it is definitely the case.

#3011: Europa Clipper

November 13, 2024
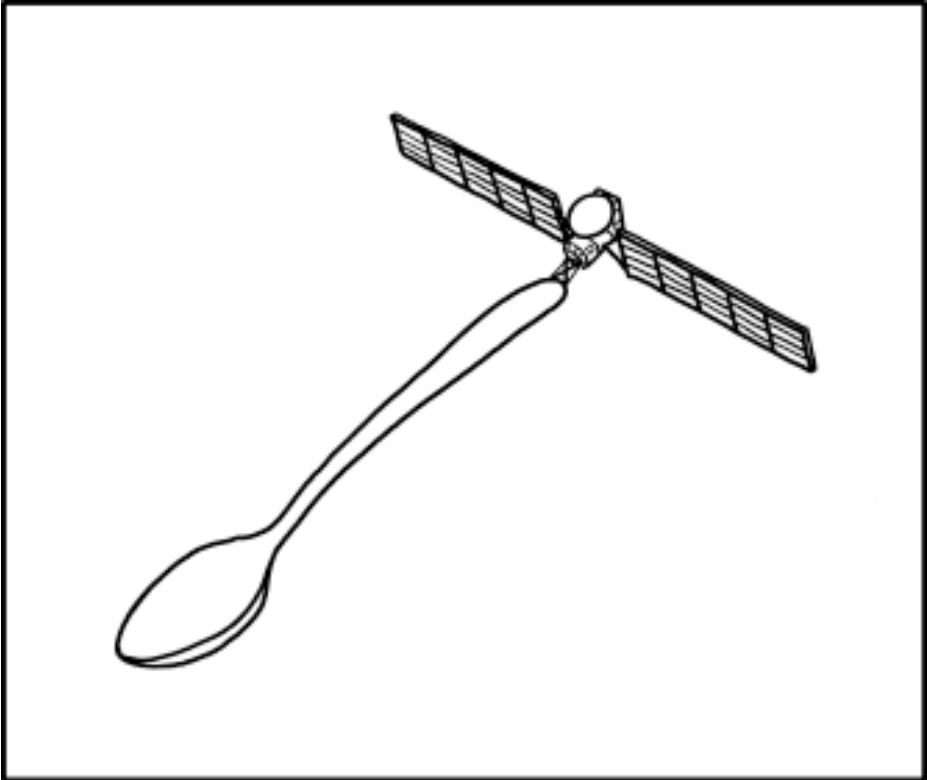
GOOD NEWS: NASA'S *EUROPA CLIPPER* IS EN ROUTE TO EUROPA AND HAS SUCCESSFULLY DEPLOYED ITS CRÈME BRÛLÉE SPOON.

They had BETTER make this a sample return mission.

Explanation

The Europa Clipper space probe was launched from the Kennedy Space Center in Florida on October 14, 2024. It is expected to arrive at Jupiter and begin exploration of Jupiter's moons, particularly Europa, in April of 2030.

Europa is an icy moon. Water ice covers its surface. Around 15 to 25 kilometers (10 to 15 miles) beneath the ice, there is expected to be liquid water which may contain some basic forms of life. To sample this liquid, its icy crust would need to be breached. The thickness of the ice dwarfs the Europa Clipper's 31 meter span.

Europa's surface of ice over liquid water could be loosely compared to the caramelized crust on the popular dessert crème brûlée—a comparison that may have been prompted because the Cassini-Huygens probe, after landing on Saturn's moon Titan in January of 2005, found that its surface had what was described as a "crème brûlée" consistency. The hard surface of the caramel cream dessert is traditionally cracked open with a spoon, so Randall jokes that such equipment will be deployed by the Europa Clipper.

In truth, no such spoon is present on the probe, and Europa's icy crust is too thick to be penetrated by a spoon of such size. Advanced measures are needed to prevent contamination of liquid water by Earth's organisms such as tardigrades, deinococcus radiodurans, or bacillus subtilis. The Europa Clipper's course has been

charted to avoid any contact with the surface of Europa (although it will fly through some sparse material it ejects into space) so as to prevent contamination by microorganisms from Earth.

The successful deployment of any spacecraft's instrument is considered a cause for celebration because deployable spacecraft instruments often fail to correctly extend, unfurl or undock. The Clipper has a magnetometer that will be used at the end of a 8.5 meter boom (not apparent in the comic which, spoon extension aside, is an otherwise fairly accurate depiction) as part of its study of the moons' environment.

The title text expands on the joke by stating that the spacecraft "had BETTER" return samples of Europa to Earth. However, the Europa Clipper is not a sample-return mission, and if it were, such samples are unlikely to be good to eat.

#3012: The Future of Orion

November 15, 2024
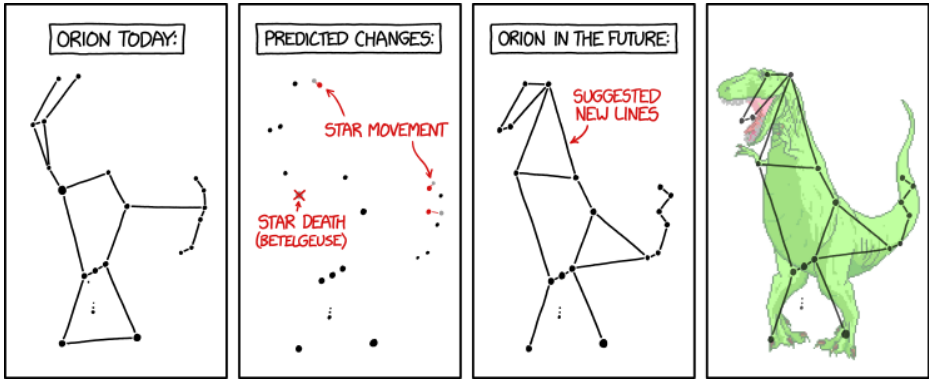
Dinosaur Cosmics

Explanation

Stars in the night sky sometimes change, occasionally varying in brightness, very rarely exploding, and imperceptibly moving. For example, Betelgeuse, a star in the constellation Orion, is expected to explode as a supernova between tens of and a thousand years, and then disappear from the night sky. And all stars move relative to us and each other, which results in apparent movement in the sky called proper motion, a function of a star's relative movement in three dimensions and its distance from us.

This comic shows changes in Orion from Betelgeuse disappearing and three of its fastest moving stars, and recommends revising the constellation (or creating a new asterism) from one which depicts a hunter to another matching a different hunter, the Tyrannosaurus from Ryan North's Dinosaur Comics.

Depending upon the artistic imagination of the observer, western (and northern-hemisphere) traditions may evoke the right 'string' of stars as either Orion's bow-arm holding a bow (perhaps having loosed an arrow towards Taurus, the Bull, with his off-arm raised aloft and behind having just released the bowstring) or else holding some creature he has caught/is fighting (with his off-arm, the other arm holding a raised club/sword that will strike the beast), with other astronomical traditions maybe 'recognising' various similar or different imageries according to their own cultural ideas (and perspective

upon the constellation, e.g. from a southern orientation). In the form adjusted to match the "dinosaur comics" image, the rightmost group becomes the creature's tail and the upper-left maps to the open-jawed head and neck. The torso and legs (the latter sometimes depicted as leading only down to the kneeling Orion's knees, depending upon the imagined pose, hence the enclosed trapezoid of either his lower knee-length robe or from one lower leg crossing the ground, excusing the apparently anomolous leg-to-torso ratio that doesn't fit a hunting human quite as much as the depicted dinosaur) are essentially the same in both versions, but mirrored in sidelong profile, with the minor difference of both shoulders' positions within the asterism, and the traditionally short and stubby T-Rex arms not being granted 'star arms' in their own right.

It should be noted that the main stars (but not the nebula) of Orion's Sword are drawn, but do not fit the dinosaur image in any way. In the original Orion constellation, they are rarely connected with the 'lines' of the constellation, but are matched against a sword (or its scabbard) when rendered as a more pictorial Orion. In the full dinosaur they match nothing from the image, but may be considered to be dripped saliva, discarded blood/torn flesh from whatever it might currently be eating or, perhaps (from its subpelvic position), other expelled material...

The proper motion of χ^1 Orionis shown near the top at the end of Orion's arm (and the back of the dinosaur's head) is 0.20 arcseconds per year, so it will traverse the

depicted angular distance of 0.84 degrees in about 15,000 years. π^1 Orionis at the top of Orion's bow (and the end of the dinosaur's tail) has a proper motion of 0.14 arcseconds per year, so it will traverse its distance of 0.87° in about 23,000 years. However, with a proper motion of 0.46 as/yr, π^3 Orionis, in the middle of the bow, will take only about 9,600 years to traverse its longer depicted distance of 1.24°. (The angular distances traversed by the stars were measured relative to the distance between Orion's two outermost belt stars, Alnitak and Mintaka, the dinosaur's hips.) Thus, the new constellation won't form until its current name has lasted more than three times as long as it already has. There are various other stars that notably move around within or near the vicinity of Orion, given suffiently long viewing time, perhaps allowing Randall some small leeway in what way to re-represent the original hunter's pose, though the 'resemblance' of the reworked constellation to its dinosaur image remains a remarkable coincidence.

There are no official constellations depicting dinosaurs. However, Draco represents a mythological reptilian dragon, and the lizard Lacerta was described in 1687. The first fossil to be later identified as a dinosaur was found in 1676, but the term "dinosaur" was not introduced until 1842. The earliest constellations in the northern hemisphere were recognized around 3000 BC. By the 2nd century AD, the Greek mathematician and astronomer Ptolemy listed 48 constellations visible from the northern hemisphere in his Almagest, following the star catalogs and globes made by Hipparchus which have
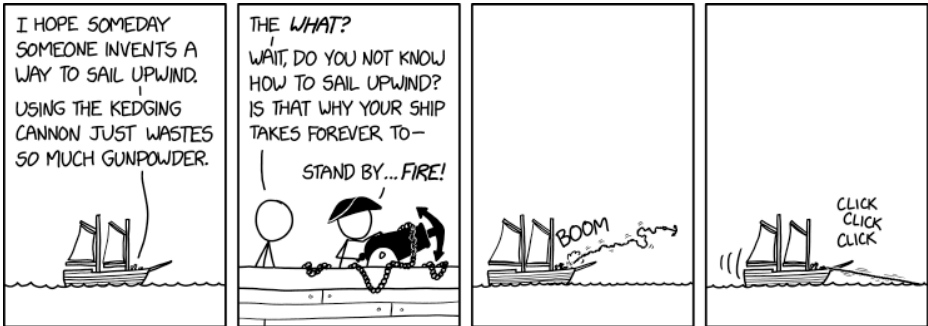
since been lost to history. The remaining modern southern constellations were mostly finalized by Nicolas Louis de Lacaille in 1756. Dozens of former constellations have been recognized, sometimes for hundreds of years, before being disregarded, replaced by others, or because they were only recognized by cultures apart from dominant Western traditions. (Polynesian navigators settled a vast expanse of the south Pacific Ocean from 26,000 to 950 years ago apparently without naming constellations, but instead recording the positions of stars on sidereal compass dials.) The International Astronomical Union established the current official list of 88 constellations in 1922.

The title text is another joke regarding Dinosaur Comics, replacing "comics" with "cosmics" because we're talking about a dinosaur in the sky.

Orion is also mentioned in 1020: Orion Nebula. T-Rex is also featured in 1452: Jurassic World. In 2006, Randall emulated the style of Dinosaur Comics with 145: Parody Week: Dinosaur Comics and he lists the comic as one of those comics he enjoys. Randall and Ryan North are known to be friends. And on the day Randall posted this comic, Ryan wrote the following in his "What are the haps my friends" section beneath his own comic: November 15th, 2024: HEY DID YOU SEE XKCD TODAY??

#3013: Kedging Cannon

November 18, 2024

Panel 1: I HOPE SOMEDAY SOMEONE INVENTS A WAY TO SAIL UPWIND.

USING THE KEDGING CANNON JUST WASTES SO MUCH GUNPOWDER.

Panel 2: THE *WHAT*?

WAIT, DO YOU NOT KNOW HOW TO SAIL UPWIND? IS THAT WHY YOUR SHIP TAKES FOREVER TO—

STAND BY... *FIRE!*

Panel 3: BOOM

Panel 4: CLICK CLICK CLICK

The real key was inventing the windmill-powered winch.

Explanation

Prior to the invention of powered ships, oceangoing vessels moved primarily by means of wind power, which meant that they were restricted by the direction and power of the winds. If a sailing vessel needs to travel upwind (against the wind), they typically make use of a technique called tacking (or "tacking against the wind") which involves zigzagging across the wind's direction, using the airfoil of the sail to exert force perpendicular to it. This method is significantly slower and more difficult than traveling downwind, but it makes upwind navigation possible.

This comic portrays a fictional scenario where a ship's captain, apparently unfamiliar with tacking, has developed an alternative method based on kedging (also known as warping).

The basics of kedging are not dissimilar to the comic: a boat affixes a rope or chain to an anchor point (such as a literal anchor) and winches itself closer. Traditionally, kedging involves deploying an anchor from the vessel, either manually or via a smaller boat, and then winching the ship toward the anchor point using ropes or chains. This is a real method, but is clearly very slow and labor intensive. Generally kedging is only effective in shallow waters and employed when tacking is not an option, as for example in harbors or narrow channels where space is tightly constricted. The captain in this strip appears to be using it for long-distance travel, which would be highly

impractical. What's more, he deploys his anchor with a cannon, wasting large amounts of gunpowder (although with the setup as depicted, wasting gunpowder would be the least of a ship's concerns, as firing something the weight of an anchor any meaningful distance would require so much force it would outright rupture just about any age of sail artillery piece).[actual citation needed] Meanwhile, a confused Cueball looks on, wondering why the Captain isn't trying to use tacking instead.

This approach to transportation has been used in war, allowing ships to maneuver without wind , but such was done with smaller boats hauling the anchor, rather than cannonfire.

Where the water is too deep for the anchor to reach the bottom, a so-called sea anchor could theoretically be used, but would be even less practical. Kedging with a sea anchor would effectively be a very slow and inefficient version of rowing, which is an alternative (albeit labor-intensive) method to travel against the wind.

Another issue with kedging is that it would take substantial energy to draw in the rope, as they'd be moving the entire ship forward. In pre-steam power ships, the obvious answer would be to draw it in by hand, but this would require a large number of people exerting a great deal of effort, and that kind of effort (once again) could be better used in rowing. The title text indicates that the captain's system has solved this by incorporating a windmill mechanism that harnesses wind

power to draw in the kedging rope. This implies that there is indeed sufficient wind that could be used for tacking, as otherwise the windmill would be ineffective. An analysis of the efficiency is below.

#3014: Arizona Chess

November 20, 2024
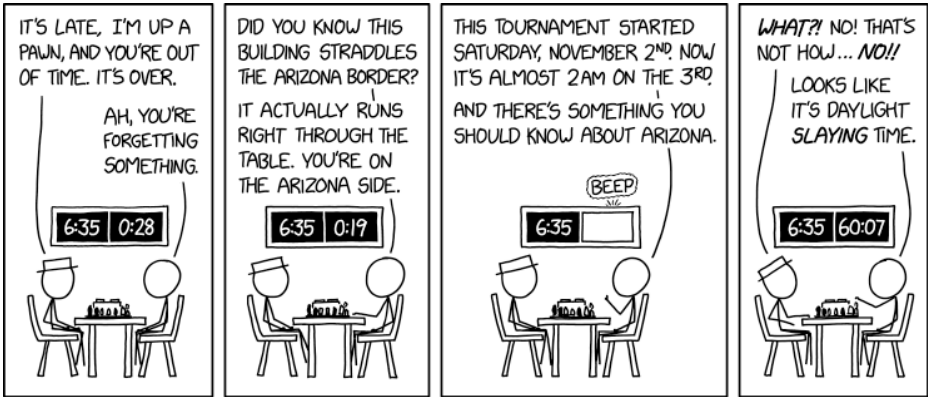
Sometimes, you have to sacrifice pieces to gain the advantage. Sometimes, to advance ... you have to fall back.

Explanation

White Hat and Cueball are playing a timed game of tournament-style chess. At the start of the comic White Hat has the advantage because, as well as having one more pawn than Cueball, he has more time left to play his remaining moves — 6 minutes and 35 seconds, versus Cueball's 28 seconds, as shown on the chess clock display above them. This means that Cueball cannot afford to consider his moves as carefully as White Hat.

However, Cueball has an unexpected advantage. The building is sited across the border of Arizona with another state (or possibly with the Navajo Nation, which DOES observe DST, see Time in Arizona), with White Hat on the Arizona side, and the game is being played at a very particular time of year, when (most of) the United States exits Daylight Saving Time, which happens at 2:00 AM on the morning of the first Sunday in November. When this happens, clocks in those other states 'gain' an hour (i.e. they show that an hour less has passed than previously). As Arizona doesn't observe Daylight Saving Time (DST), clocks there continue to progress time as normal.

At this time, White Hat's time remains normal, but Cueball's time "falls back" one hour, giving him 60 additional minutes of play time. White Hat immediately protests, likely trying to communicate that this is not how chess clocks are meant to work. They are fancy timers, tracking how much time each player has used

since the beginning of the match, and sometimes, depending on the rules of specific tournament, adding a specified increment of time every turn. They're not supposed to be based on local time, and changing the time remaining during play would certainly be a violation of the rules. Even clocks that do track local time are generally not so carefully calibrated that they would reliably switch times so close to a state line.

Using the changing local time rather than a monotonically increasing time is generally considered a bug when implementing systems like a chess clock. Most engineering libraries provide both, but the local time is much more complex to implement, and not usually included in a device as simple as dedicated hardware for a chess clock. It could be interesting to find an example of a microcontroller used in a chess clock here.

Cueball ignores these protests, and now seems confident of victory, since he has far more play time remaining. Daylight Slaying Time is a pun on Daylight Saving Time, but note that the comic takes place as the non-Arizona clock stops observing DST and joins the Arizona clock in Standard Time. A pun on Daylight Saving Time was also made in 673: The Sun.

The title text makes use of a pun. To "fall back" in a strategic sense means to withdraw from an attack, or even to retreat. This can be part of a valid strategy, as withdrawing from an engagement can consolidate your forces into a more defensible position or formation, allow you to press the attack elsewhere, at a more

advantageous time and place, or draw enemy forces into an attack under circumstances that you control. "Spring forward, fall back" is a mnemonic used for daylight saving time; we advance the clock forward when entering DST in the spring, and move it backward when leaving it in the fall (autumn).
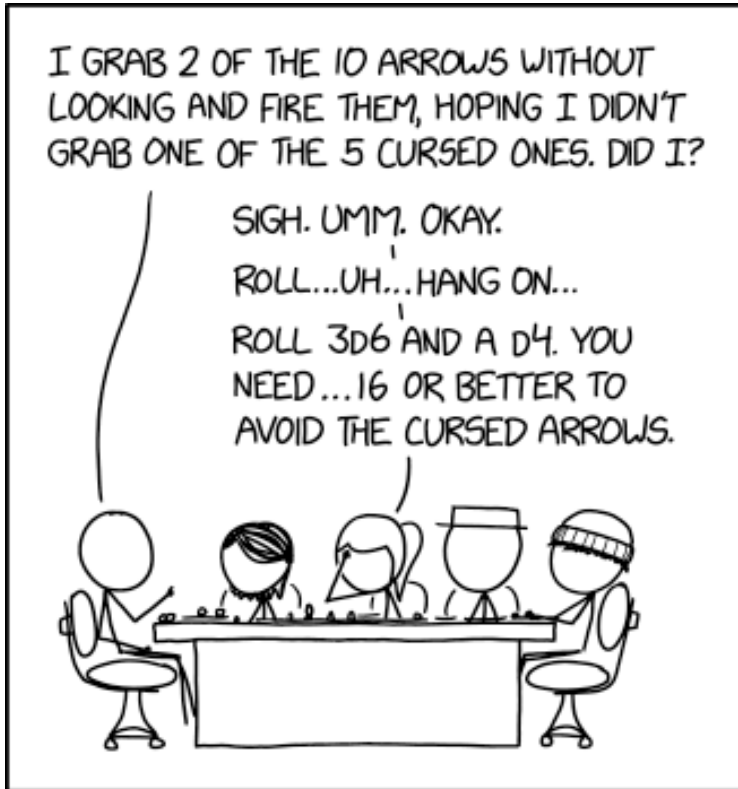
There are buildings in the US that are built across state lines (and county and city boundaries), and even some buildings that extend across international boundaries (these are known as line houses). The existence of these buildings can result in eccentric situations when laws and ordinances vary substantially between the locations. For example, a casino might be built on a state border where gambling is legal in one state but illegal in the other. In such a case, the gaming can only happen on one side of the building (the other side being reserved for other services and functions). It's not uncommon for businesses and tourist attractions to lean into the novelty of this by demarking the boundary inside the building and specifically encouraging things that are legal only on one side of the line. Such situations are likely the inspiration for this strip, but using such a line to manipulate a competition based on time zone is highly unlikely.

Ongoing state-level efforts to end time changes could also increase the number of places where this situation could happen, as more DST/non-DST boundaries arise.

The comic was published five days before the start of the World Chess Championship 2024 in Singapore.

#3015: D&D Combinatorics

November 22, 2024

I GRAB 2 OF THE 10 ARROWS WITHOUT LOOKING AND FIRE THEM, HOPING I DIDN'T GRAB ONE OF THE 5 CURSED ONES. DID I?

SIGH. UMM. OKAY. ROLL...UH...HANG ON... ROLL 3D6 AND A D4. YOU NEED...16 OR BETTER TO AVOID THE CURSED ARROWS.

I GOT *WAY* MORE ANNOYING TO PLAY D&D WITH ONCE I LEARNED THAT OUR DM HAS A COMBINATORICS DEGREE AND CAN'T RESIST PUZZLES.

Look, you can't complain about this after giving us so many scenarios involving N locked chests and M unlabeled keys.

Explanation

Dungeons and Dragons (D&D) is a tabletop role-playing game that usually has a "Dungeon Master" (narrator) that takes a team of players through scenarios where they attack monsters and go on quests.

Often, there will be semi-random events: e.g., when attacking a monster, often a player will roll a die and deal damage based on the result. D&D uses a variety of dice, from regular d6 (6-sided, cubic dice) to other polyhedral dice, with the number of faces denoted by XdY (e.g., 3d10 is a rolling of 3 10-sided dice, which each have numbers from 1 to 10 on it). Common sets include: d4, d6, d8, d10, d12, d20, and occasionally d100 (typically not, however, the d65536).[citation needed]

With these, you can simulate events with a wide variety of denominators. In this case, Cueball gives a combinatorial problem:

- There are 10 arrows.
- 5 arrows are cursed.
- You randomly take two.
- What are the odds that neither of them are cursed?

Calculating using binomial coefficients, there are "10 choose 2" (45) ways to choose two arrows, of which there are "5 choose 2" (10) ways to choose 2 arrows that are non-cursed. As a result, the odds of taking all non-cursed arrows is 10/45, which simplifies to 2/9.

To see this in a different way, the probability of choosing one non-cursed arrow is 5/10, which then must be multiplied by the probability of choosing the second non-cursed arrow, which is now 4/9, giving 20/90 or 2/9, the same result as before.

The Dungeon Master (DM) in this case has to map that probability into rolling multiple dice, whose sums are also not evenly distributed: i.e. if rolling 3d6 (3 six-sided dice) and a d4 (1 four-sided die), the sums can range from 4 to 22. It's pretty hard to do this in one's head, but it does happen that the odds of rolling 16 or more with this combination is 2/9, matching the probability that we want to simulate. Here's a table of all the 6*6*6*4=864 possible outcomes -

71+52+34+20+10+4+1 = 192

192/864 = 2/9, which matches the desired probability from earlier. The table of outcomes can either be bruteforced with a program, or can be derived using generating functions.

The caption elaborates that the DM has a degree in the relevant field, and is unable to resist applying this to the D&D game when the opportunity arises - opportunities that Cueball eagerly provides for this very reason.

There are several much easier ways of implementing this operation, without coming up with a more complex solution:

The first two options also instantly reveal cases of

whether two cursed arrows are nominally chosen (an outcome that is at identical odds to the opposite possibility of neither being so), should this be useful roleplaying information in addition to the basic fact of failing to avoid at least one of them. The option suggested in the comic could also be used to indicate this if the dice add up to 10 or lower, the fourth one if (for example) the complementary results of 2, 4 or 5 are rolled, and the final one in the event that the 'percentage' given is 0-21 (or 1-22).

One could argue that the above solutions do not have the "polished" D&D feel of rolling a certain number of dice, adding them up, and seeing if the result is greater than or equal to an entirely correct required total. This is a commonly used mechanic for difficulty checks, hit calculations, and other such chance-based events in D&D. The DM may feel that this dice format is a requirement, but this approach is far too clunky for most DMs to be practical. It may be inferred that as the DM's mind tends towards more combinatorial solutions, she is either unable or unwilling to consider more straightforward and less time-consuming solutions to this cursed arrow problem.

The title text claims that Randall only started doing this to the DM after she herself insisted on forcing another combinatorial puzzle on the players several times, involving a bunch of locked treasure chests and a multitude of keys to unlock them with. This might be a reference to an M-of-N encryption system , where a system has n valid passwords (instead of just one) but

requires m of those passwords to be given before it will open; it is assumed m is greater than 1 but less than n. While this is easy enough to implement in a computer system, it would be extremely cumbersome to build for a physical lock with keys, and spreading the mechanism across multiple separate treasure chests would be impossible without literal magic (luckily, magic is in plentiful supply in a typical Dungeons and Dragons game).[citation needed]

#3016: Cold Air

November 25, 2024
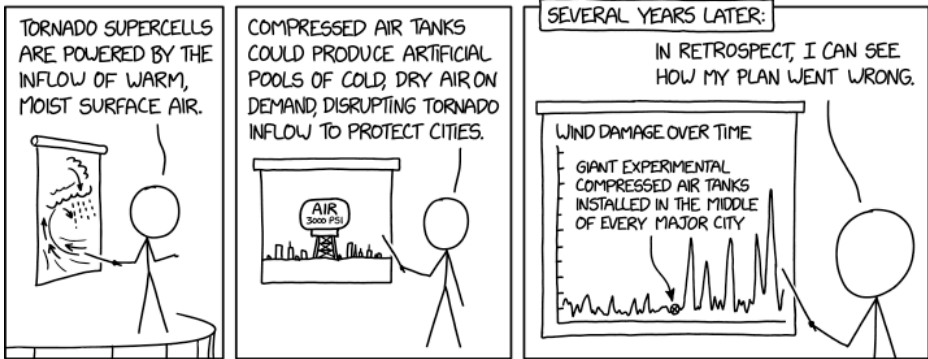
We also should really have checked that the old water tower was disconnected from the water system before we started filling it with compressed air.

Explanation

Tornadoes are vortex-driven air columns that rotate at high speeds. The wind speeds can vary from as low as 40 mph (65 km/hr), which is enough to do minor damage to some buildings and trees, to over 300 mph (480 km/hr), which is enough to level buildings, lift houses in the air, and throw automobiles at high speeds. These columns can travel over distances of several miles, causing significant damage and loss of life. Because specific conditions are required for tornado formation, certain regions are particularly prone to tornado activity (such as Tornado Alley in the US). These areas face ongoing threats from tornados, and so detecting and preparing for them is a major concern. The ability to dissipate a tornado before it does any damage would be very valuable.

In this strip, Cueball proposed a method for tornado control. He reasons that, since tornados depend on an inflow of warm, moist air, injecting a flow of cold, dry air should disrupt the cell. In order to protect inhabited areas, he suggests that large tanks of compressed air should be constructed in cities in tornado-prone areas to produce "pools" of cold dry air. The implication is that, if a tornado approaches, the tanks can be used to flood the area with cold air, which would settle near the ground and be drawn up into the tornado, as it approaches, hopefully causing the tornado to disperse.

Whether such a system could potentially work is

questionable. For one thing, the volume of air would be so vast, and air movement in such scenarios is so hard to predict, that getting enough cold air into the tornado would be extremely difficult. In addition, it's precisely the mixing of warm and cold air that produces the swirling motion that creates tornadoes. How, exactly, this cold air would interact with the tornado is a matter of speculation. However, the final panel suggests that the plan failed for more basic reasons. Storing the vast quantity of air required would be a massive engineering challenge. The final chart refers to the point where "giant experimental compressed air tanks" are installed in populated areas, and shows that wind damage massively increased after this happened. The implication is that wind damage caused by the tanks themselves far outstripped the effects of tornadoes. The massive, discrete spikes suggest that this is caused by specific, major, damage events.

According to the label on the proposed tank, it would be pressurized to 3,000 psi. Given the scale of the buildings in the picture, the tank must be vast, possibly hundreds of feet in diameter. Simply building a tank that large to hold that kind of pressure would be exceptionally difficult, and any failure would be potentially catastrophic. Any kind of release from the tanks, whether due to valve failure (or accidental opening), pipes failing or being damaged, or the tank itself developing a rupture, would release very high pressure air, potentially at sonic velocities. Given the size of the tank, the amount of air released could be huge, and it would be directly adjacent

to buildings, creating high risk of major damage. Because this damage would be done by moving air, it could be considered "wind damage", even though it's artificially generated.

An even greater danger would be if the tank were to burst altogether, which is a real danger in pressurized vessels. A sudden and uncontrolled release of air at 3000 psi is effectively an explosion. Given the enormous size of the tank, that explosion would quite certainly be enough to level the surrounding buildings.

The upshot is that, even if this proposal could fulfill its intended purpose (and it's not clear that it would), the risks that it would introduce would massively outweigh any benefits.

In the title text, it is revealed that the water tower they were using to store the compressed air was still plumbed in to the water mains. Given the pressure required for the tower to work properly against tornadoes and the fact that water is nearly incompressible, the pressure from the tower would have been nearly instantly transmitted into the water distribution system. The best case scenario would have been 'just' to have dangerously highly-pressurised water jetting into sinks, bathtubs and toilet cisterns whenever they were used; more severe consequences could be catastrophic failures of pipes and plumbing.

Using technology to disrupt tornadoes before they form was a plot element in Liu Cixin's novel Ball Lightning,

and other works. In reality, fringe scientist Prokop Diviš (1698-1765) proposed a weather-control machine to disrupt thunderstorms before they form, and there are occasionally discredited ideas made to control other weather events.

#3017: Neutrino Modem

November 27, 2024

CHECK IT OUT—45ms PING TIMES TO EVERY SERVER ON EARTH!

THAT 99.999999999% PACKET LOSS IS PRETTY BAD, THOUGH.

NETWORKING TIP: YOU CAN MINIMIZE WORST-CASE LATENCY BY LOCATING YOUR NODE AT THE CENTER OF THE EARTH AND COMMUNICATING WITH THE SURFACE USING NEUTRINOS.

Our sysadmin accidentally won a Nobel Prize while trying to debug neutrino oscillation error correction.

Explanation

Neutrinos are tiny, chargeless, ghostly particles that barely interact with solid matter at all. Despite trillions of neutrinos passing through your body every second, one will hit you only once every 10 years or so.

In this comic, Randall gives a helpful tip to networking companies: in order to avoid latency issues with their servers, simply relocate their networking node to the Earth's core and use neutrinos to communicate with the surface, rather than radio waves, electrical impulses, photons in fiber-optic cables, etc. Since the core of the Earth is approximately equidistant from every point on Earth's surface, and nearly all neutrinos pass through solid matter unaffected, this allows communication with any server or network node anywhere on Earth, all with the same near-light-speed latency and without having to install wires, fiber optic cables, or anything else along the way. However, the cost is an unbelievable amount of lost data, since only a teeny teeny teeny teeny tiny (teeny4 tiny) fraction of the neutrinos sent from the modem will actually be received by the servers on the surface, and the same again for those neutrinos that make the return journey: the specified packet loss amounts to 1 in 100 trillion packets completing the journey, with the rest missed (for reference: the lower threshold for acceptable packet reception is 98 in 100). If symmetrically failing to be detected, this suggests that only one in 10 million neutrino 'packets' is being received by the remote server, and only one in 10 million of the prompted replies are

being received at Cueball's end.

This may still be a vastly better rate than expected. Neutrino detection with vastly bigger detectors than Cueball's device may only detect a fraction of the necessary neutrinos. Perhaps a little over 60 billion neutrinos per cm² per second pass through the Earth from the Sun, but detectors much larger than the whole of Cueball's indicated living space tend to detect no more than a few hundred of those per day. As the neutrino modems, at either end, must also generate (and, ideally, aim) their own modulated neutrino traffic, what proportion of the modem is usefully detecting is debatable. Beyond this issue, network packets consist of a series of signals to convey purpose, routing information and other overheads (including error detection and correction, which may be particularly important in this case). Even if direct point-to-point transmission (assumed, at least in this respect, to be reliably targeted) removes the need for full routing overheads, each ICMP echo request and reply will still require a significant number of neutrino events to be triggered, and then sufficiently detected for what they are, to be of any practical use.

A time delay of 45 ms is the approximate round-trip time for light (or neutrinos, which move nearly as fast) to travel the distance from the center of the Earth to the surface and back. Visible light, of course, couldn't make this journey through the rock at all. Perhaps only very long wavelength electromagnetic radiation could reliably penetrate half the Earth, which would give (like these

hit-and-mostly-miss neutrinos, but still vastly better) a very low effective bit rate. This has the opposite issue of using a Sneakernet connection, where a reliable but physically slow transfer protocol (as discussed in What-If: FedEx Bandwidth) can potentially reliably deliver huge amounts of data in a single successful communication.

There are also, of course, the practical problems of constructing a facility at Earth's core, which is extremely far away (~6400 km / 4000 mi underground), extremely hot (~6000°C / 6273K / 11292°Ra / 8400° / −5900°real C) and under extremely high pressures (~3½ million atmospheres / 50 million PSI).

Ponytail and Cueball are shown floating because a hollow space in the center of a body experiences near-zero gravity. This is because all the mass of the object is evenly distributed in all directions. While there is 4,000 miles of rock "above" you pulling you "up," there is also 4,000 miles "below" you pulling you "down", with much the same amount left, right, front, back and every other direction, so you experience net-zero gravitational acceleration.

The title text refers to neutrino oscillation, which is a phenomenon in which neutrinos change between three different "flavors" - electron, muon, and tau neutrinos. A Nobel Prize was in fact awarded for the discovery of neutrino oscillation, which implied that neutrinos have mass, albeit an extremely tiny amount ($< 2.14 \times 10-37$ kg for the sum of the three flavors). The "neutrino

oscillation error correction" could refer either to a way to correct for errors in the signal introduced due to neutrinos oscillating, as above, or for the method of error correction that cleverly uses modulated neutrino oscillation to its own advantage. Either of these could perhaps be considered such extraordinary developments as to make the system administrator involved deservedly elegible of a Nobel Prize, or perhaps one or other close equivalents.

#3018: Second Stage

November 29, 2024

WE HAVE LIFTOFF.

MAIN ENGINE CUTOFF. STAGE SEPARATION CONFIRMED.

WE ARE GO FOR SECOND STAGE BURN.

SECOND STAGE?

YES. ...WHAT?

WERE WE SUPPOSED TO HAVE A SECOND STAGE? ...YES!

DID *YOU* SET UP A SECOND STAGE?

I THOUGHT *YOU* WERE HANDLING STAGING!

OH NO.

OKAY, DON'T PANIC. LEMME SEE IF WE CAN ORDER A STAGE ONLINE FOR SAME-DAY DELIVERY.

SIGH.

HEY, WHAT ZIP CODE SHOULD I PUT? OURS KEEPS CHANGING.
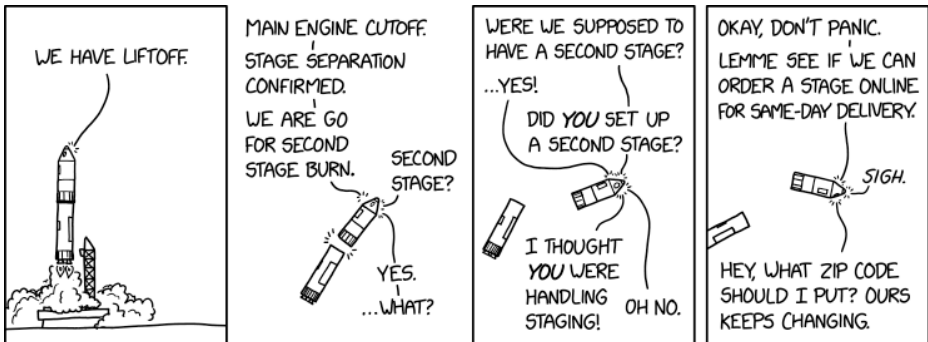
Hmm, they won't do in-flight delivery, so let's order a new first and second stage to our emergency landing site and then try to touch down on top of them to save time.

Explanation

In this comic, two people have lifted off in a staged launch vehicle without their second stage installed, an unlikely scenario in reality because rocket launches are thoroughly planned and checked. The lack of an entire stage would be glaringly obvious to anyone who is part of the project.[citation needed] But it can be a problem in games such as Kerbal Space Program.

Staging in rocketry refers of the segmentation of a launch vehicle into distinct, separable modules, each one with an independent Rocket engine (or engines) and fuel supply. This is practiced for two critical reasons: firstly, different engine designs work better at different altitudes, so you'd want to use one engine type deep in the atmosphere and a different engine once you get to space; and secondly, since you only need one of those engines (or sets of engines) at once, it'd be better to simply expend the first engine(s) and its fuel tank once you no longer need it. By getting rid of that useless mass, you can go farther using the same amount of fuel. A launch vehicle that does not employ staging is called an Single-stage-to-orbit (SSTO), but none of them have been successful due to the technical challenges. There's a tradeoff between the greater effectiveness of different engines under different conditions, and the mass penalty of having to have multiple engines as well as extra hardware that can be separated.

As Pilot 1 calls to fire the second stage, Pilot 2 is initially

confused and asks if a second stage was needed. Pilot 1 confirms that there was supposed to be a second stage, and thought that it was the Pilot 2's responsibility to install and confirm there was a second stage. When both pilots realize there is no second stage, Pilot 2, naturally, thinks he can order one on Amazon with same-day delivery (though Amazon typically doesn't sell space ship stages — at least not with same-day delivery).[citation needed] He then has difficulty picking an address ZIP Code as they are likely traveling too high above the ground and too fast to be in a single postal area for long enough for the delivery to take place. The joke is likely poking fun at people who forget to pack certain items when going on road trips or vacation, and rely on Amazon to deliver replacements to them. There is also humor to be found in this rocket apparently being designed, built, and piloted by only a couple of people — in real life, the construction of a rocket, especially a manned one, generally involves thousands of people. Although test pilots often have input in the development of many vehicles, and many were chosen for various space programs, generally they do not do the designing themselves. There are possibly some notable exceptions to this — but with varying degrees of credibility, and almost certainly none that did any better than those voices in the comic.

The comic also alludes to a not-so-distant future when space travel is a much more mundane endeavor. If companies such as SpaceX succeed in their mass-production and launch cadence goals, one could

imagine a scenario where rocket parts become standardized and easily replaceable — similarly to how it is easy today to replace a car's tire or fill its fuel tank if you get stranded on a highway. This might create an ironic situation where the space ship being launched into orbit or into outer space that is missing its second stage would need another, even faster, space ship (with its own second stage) to deliver the second stage to the first ship. And what if the delivery ship forgot its secondary stage?

In the title text, Pilot 2 concludes that in-flight delivery won't be possible but proposes to have a new first and second stage delivered to their emergency landing site, properly stacked, so they can simply land on top of them, attach, and immediately take off again. This is not too dissimilar to how SpaceX is proposing to rapidly turn around Starship launches atop its Booster stages; though not yet close to being proven possible and practical, a Starship would descend to be caught by a 'Mechazilla' tower, ready to be relaunched from there atop an awaiting Booster stage that had also been recently 'delivered' (perhaps by itself having been recently caught, having returned from the same or another recent flight) with perhaps minimal additional preparation other than whatever refuelling is required.

This is not the first time Randall discusses the idea of a mid-flight delivery. A What If? explanation attempts to answer if it possible to have pizza delivered to you, by a bird, while flying on a commercial airliner.

#3019: Advent Calendar Advent Calendar

December 02, 2024
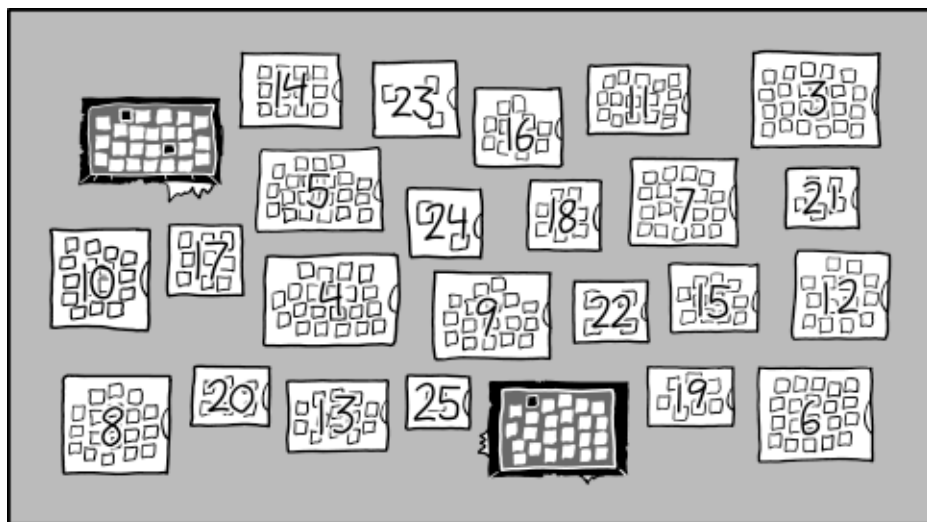
I LIKE ADVENT CALENDARS, SO I GOT AN ADVENT CALENDAR
THAT GIVES ME A NEW ONE EVERY DAY UNTIL CHRISTMAS.

The growth rate of items per day may may seem absurd,
but it's actually much less than the acceleration in the 12
Days of Christmas song.

Explanation

Advent calendars are a form of countdown to Christmas consisting of a card or structure with one closed "window"/opening for each day. Every day, another "window" is opened (e.g. a cardboard flap is opened along perforations), revealing a small present (traditionally, just a thematic picture or chocolate). While the religious season of Advent traditionally begins four Sundays before Christmas, most Advent calendars begin on December 1st for simplicity. In 2024, when this comic was published, the Advent season coincidentally starts on December 1st. Advent calendars usually have either 24 or 25 doors (ending on either Christmas Eve or Christmas Day), depending on manufacturer's choice and/or local tradition.

In this comic, Randall has devised an Advent calendar that contains multiple smaller Advent calendars, each of which contains the same number of items as there are days left until (and including) Christmas Day. By the time he reaches Christmas, he will have 325 different items, or 350 if counting the sub-calendars. The calendar is shown as it might be on December 2nd, the date of publication of this strip. The "window" in the upper left, presumed to be for the 1st of December, has 25 sub-windows, of which two are open. (One would have been opened on December 1st and the next for the day after.) The "window" 5th from the left in the bottom row, probably for December 2nd, has 24 sub-windows, of which one (that for the initial 2nd) is open.

The title text refers to The Twelve Days of Christmas, a traditional Christmas carol in which the singer receives one set of gifts from their true love for each day of the Twelve Days of Christmas. On day one, they receive one gift, and on day n, they receive again all the gifts they received on day n-1, plus n copies of a new gift. The exact gifts given each day vary by version of the song, receiving 78 gifts on day 12, for a total of 364 gifts. For the Advent calendar Advent calendar, each day a number of items equal to the number of days left until Christmas are added. There are 364 items total in the 12 Days of Christmas, the final day itself having exceeded the gifts of the nested calendars (the sub-gift count being 325, and regardless of the 25 calendars also being included). However the advent calendar uses 25 days rather than just 12, hence the song's acceleration in number of gifts each day is much higher. The title text says "may" twice, either mistakenly, or maybe on purpose since the comic's name has word duplication.

It is not clear what is inside each sub-calendar. The typical filling would be chocolate, however it could also be possible that the advent calendar advent calendars had even more advent calendars within. That this is not the case is revealed in the title text as, if they were (and were run concurrently), the number of (sub-sub-)gifts would always equal those in the song.

#3020: Infinite Armada Chess

December 04, 2024
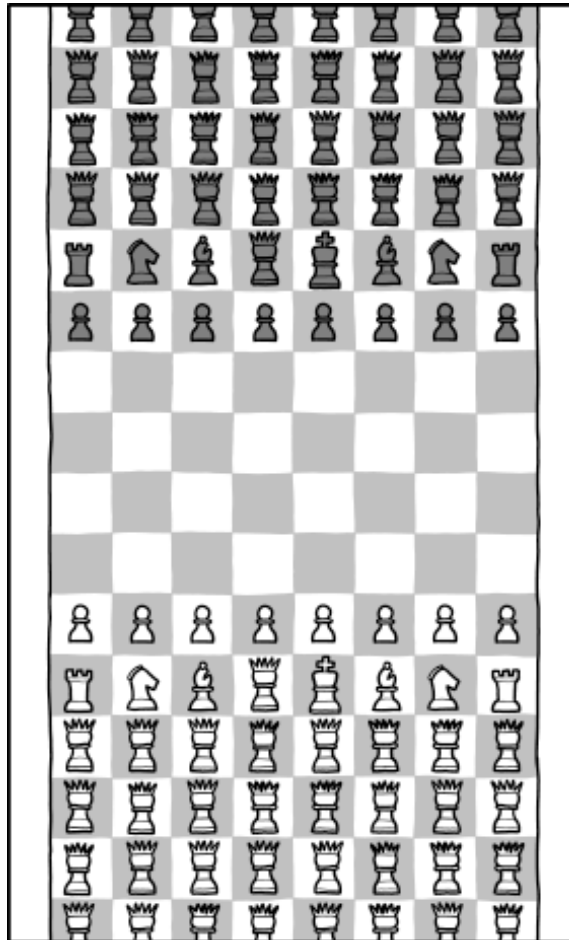
INFINITE ARMADA CHESS

Stockfish 16 suggests the unconventional opening 1. RuntimeError: Out of bounds memory access

Explanation

Chess is a board game played between two players on an 8x8 chessboard. In standard chess, each player has 8 pawns and 8 other pieces: 2 rooks, 2 knights, 2 bishops, a queen, and a king. Chess variants are chess games in which the rules, board sizes, and/or piece behaviors are altered. In the chess game presented here, a non-standard chessboard is used, which extends vertically past the original 1st and 8th ranks off the page to infinity in both directions. Each square beyond the 8 standard ranks is filled by an additional queen. The queen is the most powerful piece on the chessboard, having the powers of a bishop and a rook combined. With an infinite armada of queens, each player will have more resources to call on. Sometimes having a bunch of queens doesn't go very well, however (here, try knight to d6).

In the title text, Stockfish is a chess engine designed to evaluate a chessboard and find the best move. However, it is designed to handle finite boards, so it's likely that some problem will occur as it runs on an infinite one. Here that problem shows up as the game's move #1, "RuntimeError: Out of bounds memory access". This error message is unique to the cross-browser WebAssembly implementations of WebGL, so there was probably not enough memory to render an infinite board in a web browser window.

All but a finite number of pieces are stuck at every step, and thus there are only a finite number of possible

moves, but the game is unbounded (each capture resets the draw clock) and each capture also increases the number of possible pieces which can move by opening up more space on the board. No finite amount of space is guaranteed to suffice to analyze the game — contrast with standard chess in which surprisingly little memory (given impossibly vast, but finite, amounts of time) is needed to play perfectly. Still, as in regular chess, a program which understood that only a finite number of pieces are accessible could play the same way programs play conventional chess.

However, without specifically coding Stockfish to be aware of the logical certainty of the infinite number of queens being blocked, it is likely to still be checking every piece in turn, long after it has successfully prepared to establish (or perhaps actually explored) the relative strategical advantages of undertaking the twenty initial moves that White could make. Or, in the algorithm's worst case scenario, it has tried to start its movement-checking process at the 'rearmost rank', and has encountered the error before managing to establish (let alone assess) any valid opening moves. By easy induction, the human player should be able to establish an intrinsic understanding that everything behind two full ranks of undisturbed pieces (or beyond them, when applied to the opponent's position on the other side of the board) is unable to move, where no gaps exist to shuffle around in, but the code (if designed for finite, though perhaps arbitrary, boards) is unlikely to natively have the complexity to derive this computational detail

from first principles, or even establish that it might hit a halting problem failure should it somehow avoid the issue of resources.

This comic was published in the middle of the 2024 World Chess Championship, between the World Champion Ding Liren and the Challenger Gukesh Dommaraju.

#3021: Seismologists

December 06, 2024
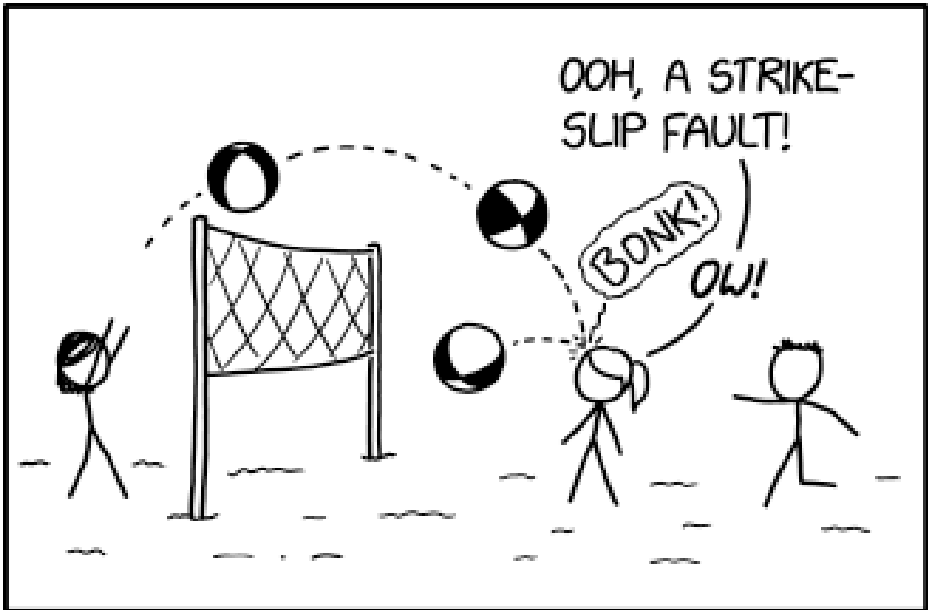
WHY SEISMOLOGISTS ARE BAD
AT BEACH BALL VOLLEYBALL

And even when they're not distracted, they usually get kicked out for illegal under-the-net 'subduction spikes'.

Explanation

In seismology, a "beachball" diagram is a graphic that is used to show the type of slip that occurs in an earthquake. There are three types of slips: strike-slip, normal, and thrust, each with a corresponding beachball diagram. Ponytail is playing beach ball volleyball, also known as beach volleyball, a form of volleyball played with a beach ball. She appears to be playing at the beach judging from the rough texture of the ground. She is distracted by the resemblance of the rotating two-shaded beach ball to a strike-slip beachball diagram (something she uses in her field of study) and fails to play the ball, causing her to be hit on the head.

The comic could be seen as playing on the dual meaning of the word "fault". In geology, it refers to a fracture or zone of fractures between two blocks of rock, which can allow them to move past each other. In volleyball, a "fault" refers to a play violation that causes a team to lose a point. Had her opponent committed a fault within the rules of the game, the point would be finished, and there would be no reason for Ponytail to attempt to play the ball.

The subduction referred to in the title text occurs when one tectonic plate slides underneath another. In volleyball, a spike is a type of shot, typically the third of a team's three allowed touches, hit hard over the net from high up down toward the floor on the opponent's side. A "subduction spike" would be a spike hit under the net,

and would indeed not be legal and would result in a point for the opponent. Subduction is mentioned in several other comics: Beret Guy once obtained a subduction license, and it was mentioned in 1829: Geochronology and again in 3059: Water Damage.

#3022: Making Tea

December 09, 2024

WAYS OF MAKING TEA

BY HOW ANGRY BRITISH PEOPLE GET WHEN AMERICANS DO THEM

MORE ANGRY →

MAKING IT IN A KETTLE

BOILING WATER IN A POT, STEEPING IN A MUG

MAKING IT IN A CHALICE AND AMPULLA STOLEN FROM THE CROWN JEWELS

MICROWAVING A MUG
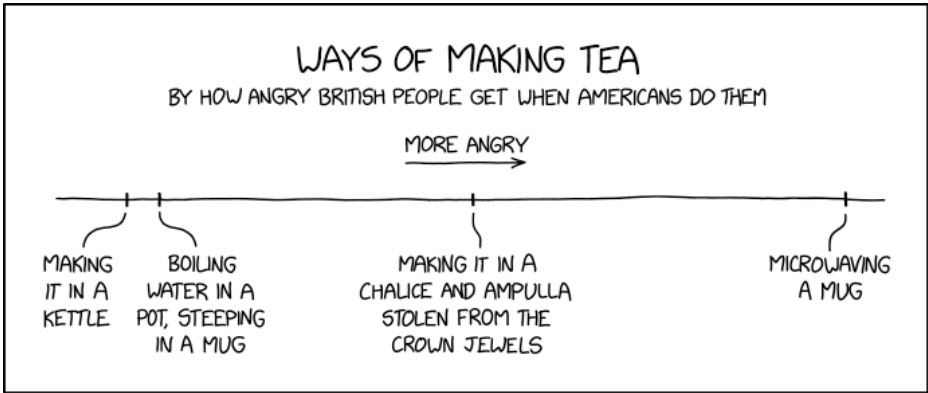
No, of course we don't microwave the mug WITH the teabag in it. We microwave the teabag separately.

Explanation

Tea is exceptionally popular in the United Kingdom (although decreasingly so, and not as serious a business as in Japan and China). Electric kettles are a standard appliance in British homes (used to boil water for tea, coffee, soup powders, instant mash, etc) and teapots and other related crockery can be found in many cupboards, or even on a shelf in full display, whether or not regularly used. British people are perceived as taking tea seriously, having very specific and strongly held opinions on the proper way to make tea. In contrast, tea (especially hot tea) is less commonplace in the United States of America (Randall's native country), and few people are particularly serious about it. Coffee is a much more common hot beverage, and both homes and offices are far more likely to have automatic coffee makers than electric kettles. While some US households have kettles that can be put on a stove top, many do not have any specific device to boil water. As a result, when Americans need a cup of hot water — for tea or otherwise — the options are usually to use a pan on the stove, or to simply microwave a mug of water (the latter probably being more common in modern times).

British people are stereotyped as taking genuine offense to microwaved water, believing it to be an objectively incorrect way to make tea. Randall mocks this stereotype through exaggeration, saying British people would be significantly less offended by someone stealing the Crown Jewels and using those for tea-making than they

would be by tea made with a cup of microwaved water.

Methods mentioned[edit]

Other tea controversies[edit]

Other sources of controversy in the correct way to make tea are not covered in the comic, or hidden behind the other 'obvious errors'. Perhaps primary among these is the question of the difference between making (and steeping) the tea in a teapot and pouring the water over a teabag in a mug.

The former tends to be a more formal method, to serve in polite company, or from the traditional need to prepare a large volume of tea for an indeterminate number of recipients and refills, such as in a canteen/cafeteria situation, where the 'pot' stays hot for almost as long as the supply lasts. A prepared teapot of tea allows a fairly consistent 'brew' that is readily poured out into teacups (or mugs) as and when required, and can be readily topped up if an increase in the supply is needed.

The latter method relies upon individual teabags or loose-leaf tea in an individual infuser, and lets each recipient leave the tea in for as long as they personally prefer (or end up having to), which reflects more individual flexibility. Again, this splits between 'high' and 'low' class use. The infamous "builders' tea" often has the teabag left in for a long time (even during drinking), with plenty of milk and sugar, to perhaps produce an increasingly dense brew as the workman concerned takes opportune sips as he (usually) can during his work. Conversely, the trend in more stylish restaurants and tearooms tends to be to supply each customer their teacup together with an individual small vessel of freshly boiled water (rarely more than one or two cups-worth) and

the recipient's choices of bagged tea (including fruit/herbal) and additions (milk, or equivalent, lemon, etc, plus sweeteners of all kinds), letting them prepare their own infusion exactly in their own way; this is often presented with an air of 'continental sophistication', but may bemuse and confuse the more down-to-Earth British tea-drinker used to their home method, as does the choice of dozens of fancy coffees from a barista when they'd be happy enough with a decent "instant coffee".

The issue of whether the milk (not obligatory, but decisively traditional) should be put in before the tea (or teabag!) is also often considered Serious Business...

In January of 2024, Michelle Francl, Ph.D., a chemistry professor at Bryn Mawr College in Pennsylvania, suggested putting a pinch of salt into tea, saying that the sodium in salt blocks the bitter taste of tea. This prompted a great outcry by The Guardian and a statement by the US embassy on X (Twitter): "Today's media reports of an American Professor's recipe for the 'perfect' cup of tea has landed our special bond with the United Kingdom in hot water ... We want to ensure[sic] the good people of the U.K. that the unthinkable notion of adding salt to Britain's national drink is not official United States Policy. And never will be. ... The US embassy will continue to make tea in the proper way – by microwaving it."

#3023: The Maritime Approximation
December 11, 2024

$$\pi \text{ MPH} = e \text{ KNOTS}^*$$
$$^*\text{CORRECT TO} < 0.5\%$$

THE SAILOR'S VERSION OF $e^{i\pi} = -1$

It works because a nautical mile is based on a degree of latitude, and the Earth (e) is a circle.

Explanation

Mph (miles per hour) and knots (nautical miles per hour) are both units used to express speed, including that of vehicles. Miles per hour are typically used in the US, UK and some smaller countries for the speed of cars and other similar vehicles, while knots are used by many sailors and pilots to describe the speed of ships and aircraft. Novice sailors or pilots, or those who spend a lot of time on land, may find it helpful to quickly convert between mph and knots, in order to relate to typical ground-surface speeds.

This could be done in the form of 1 knot = 1.2 mph, or 1 mph = 0.87 knots (1 knot = 1.85 km/h and 1 km/h = 0.54 knots for metric navigators). Randall has humorously noticed that π mph ≈ e knots: π mph = 2.72997 knots, while e ≈ 2.71828.

Knots are related to the circumference of the Earth, which can introduce π, but this is only "useful" if you want to express your speed as a fraction of the radius of the Earth: 1 knot = 1 nautical mile per hour = 1/60 of a degree of Earth's circumference per hour = 1/21,600 of Earth's circumference per hour = 2π/21,600 x Earth's radius per hour. However, nowadays this is an approximation, because a nautical mile is defined as exactly 1852 m, which is not exactly 1/60 of a degree of Earth's circumference.

The observation of the interesting near identity between

MPH and knots in the comic is misleading, because it is not exact, but only correct to a certain percentage, unlike the identity it is compared to: Euler's Identity, which is exact and expresses a deep mathematical insight, which is what makes the latter truly remarkable. The former is nothing but an unimpressive, if mildly interesting coincidence. This isn't helped by the fact that the comic carries the implication that this neat, easy-to-remember identity is actually useful for sailors, when really, being easy to remember is all it has going for it: it doesn't make calculations any easier, it is impossible to do without a calculator or paper, and doing it on paper is much harder than other conversions, given that π and e are both irrational and transcendental. Finally and most importantly, this conversion between knots and MPH is far far less accurate than the typical conversion factor used, i.e. 1.1508, which is accurate to within 0.00179%; about 280x better than Randall's. This can make a huge difference on shipping routes, which can be hundreds or thousands of miles long.

The title text furthers the joke that this identity between MPH and knots is truly fundamental, but through faulty logic. Whenever π shows up in an equation, the claim made by many mathematicians is that there is a circle hiding somewhere in the math. Randall says that π is coming from the fact that nautical miles are based on the fact that the Earth is round, and shipping routes over its surface are circular. As profound as this sounds, it makes no mathematical sense at all. He also claims that e is in the equation because 'Earth' starts with an E, which is

nothing but word play.

The equality shown in this strip consists of several different parts:

π mph × (1609.344 meters/statute mile ÷ 1852 meters/nautical mile) ≈ 2.729969 knots. The result is only about 0.43% larger than e knots ≈ 2.71828 knots.

Randall has in the past made similar observations of different dimensions that equal each other with comics such as 687: Dimensional Analysis, where he compares Planck energy, the pressure at Earth's core, the gas mileage in a Prius, and the width of the English Channel to π. In addition, in What If?, he has compared the mass of Earth to be π "milliJupiters," or π times the mass of Jupiter divided by 1000, and noted that the volume of a cube with side lengths of one mile is roughly similar to the volume of a sphere with a radius of 1 kilometer. In 217: e to the pi Minus pi and 1047: Approximations, Randall gives a lot of similar numerical approximations.

Arguably, as safe operating speeds for particular aircraft/watercraft may bear little relationship to (for example) road vehicle speeds, it might be better just to develop a separate 'air sense' (perhaps mostly at higher velocities, far above any landmark that you might pass by) or 'water sense' (often at lower velocities, and with the particular fluid nature of the water's surface) that is keyed especially to the knots-rated speed of your vessel, without attempting to carry over this aspect of any pre-existing 'road sense'. One hopefully rare exception

might possibly be in the event of a plane having to make an emergency landing on a public highway, where it could be useful to know if a (possibly unpowered) plane's final landing speed can be made to be not too far off that of any unsuspecting road traffic that you may have to land in the midst of; but this would never be a trivial endeavour in any case, and even having to attempt such a feat probably means you have few options open to you and very little time to consider many of these finer details.

#3024: METAR

December 13, 2024

DECODING A METAR REPORT:

"METER" (USUALLY MISSPELLED)

STATION ID

TIME (25:16:002)

WIND SPEED HAS BEEN 18,035 KNOTS FOR A GOOD 45 MINUTES NOW

OBSERVER IS A SIZE 6 SMALL

SORRY, THE STATION CAT WALKED ON THE KEYBOARD

METAR KNYC 251600Z 18035G45KT 6SM VCFCFZVA

+BLUP NOSIG LTG OHD A3808 RMK A02 SLP130=

WEIRD NOISE THE SKY MADE EARLIER

OBSERVER HAS NO SIGNIFICANT OTHER :-

WE OVERHEARD SOMEONE SAYING THERE WAS LIGHTNING

HEY LOOK, AN AIRBUS A380-800!

REMARKABLE!

FANFIC ARCHIVE EQUIPPED WITH A PRECIPITATION SENSOR

OBSERVER GOT SLEEPY AROUND 1:30

In the aviation world, they don't use **AM/PM** times. Instead, all times are assumed to be **AM** unless they're labeled **NOTAM**.

Explanation

In aviation, the METAR (Meteorological Aerodrome Report) is used to give pilots a brief overview of the current meteorological conditions at an airport or other suitably equipped location. The METAR follows a specific structure and makes heavy usage of abbreviations, which makes it hard to read for anyone not familiar with it. The comic makes fun of that by assuming meanings of the METAR words based on what non-aviation people might think they mean. The METAR in the comic is fairly alarming, describing dangerously fast winds, a possible tornado, freezing volcanic ash (in New York!), lightning, and impossibly high atmospheric pressure.

#3025: Phase Change

December 16, 2024
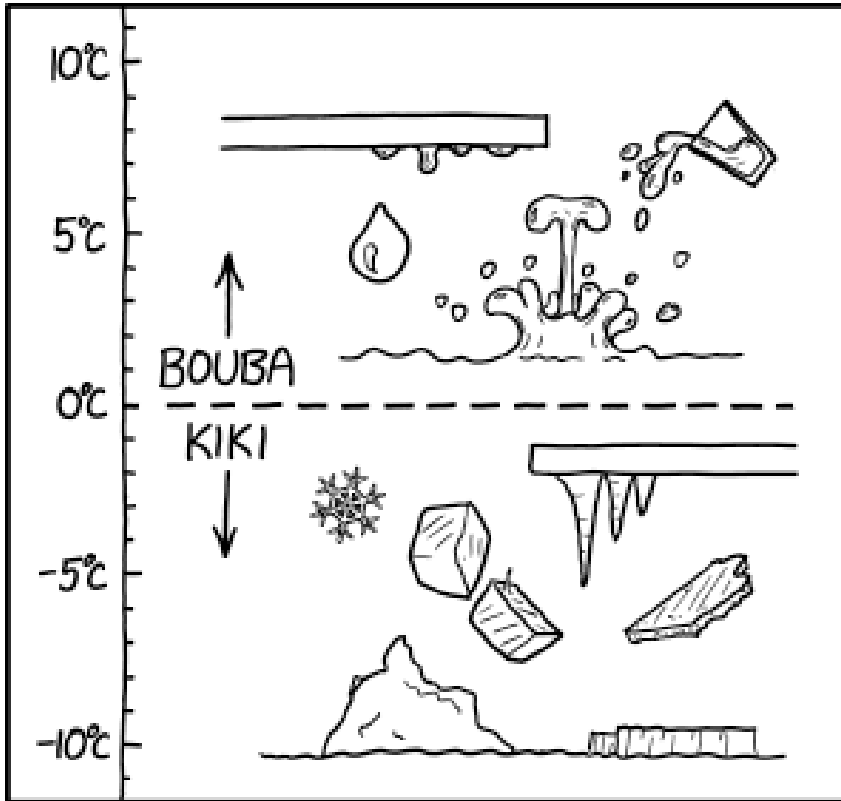
WHEN WATER'S TEMPERATURE FALLS BELOW 0°C, IT UNDERGOES A PHASE TRANSITION FROM BOUBA TO KIKI.

Even when you try to make nice, smooth ice cubes in a freezer, sometimes one of them will shoot out a random ice spike, which physicists ascribe to kiki conservation.

Explanation

This comic is a reference to the bouba/kiki effect (the cutest-sounding scientific effect!), which finds that people, regardless of what linguistic and cultural background they come from, have a tendency to associate lower-pitched sounds (such as "bouba") with objects that are big and round and higher-pitched sounds (such as "kiki") with smaller and sharp objects. Some real life examples are the antonyms 'high-low', 'rigid-flowing', and 'tiny-huge'. This is partly due to humans' needs to categorize things.

The comic intentionally conflates this with the phase transition that water undergoes around 0 degrees Celsius. Water in its liquid state can be described as soft and round, as can the sound of the word "water" itself. In contrast, ice is hard and crystalline, giving it the potential to form hard edges and sharp points. The word "ice" also contains a sharp hissing sound.

In the above-freezing section of the graph, there are pictures associated with the following (bouba) words: drop, drip, pour, splash. In the below-freezing section of the graph, the pictures are associated with the following (kiki) words: ice, icicle, snowflake, ice cube, iceberg.

The title text refers to ice spikes, which are caused by the uneven freezing of ice in a freezer. The title text expands on the joke by claiming that ice cubes wish to maintain the pointiness of objects characterized as "kiki."

#3026: Linear Sort

December 18, 2024

```
FUNCTION LINEARSORT(LIST):
    STARTTIME = TIME()
    MERGESORT(LIST)
    SLEEP(1E6*LENGTH(LIST)-(TIME()-STARTTIME))
    RETURN
```

HOW TO SORT A LIST IN LINEAR TIME

The best case is O(n), and the worst case is that someone checks why.

Explanation

Sorting algorithms are a fundamental part of computer science, with various methods differing in efficiency, ease of implementation, and resource usage. Efficiency is often described using Big O notation, which expresses how the runtime of an algorithm scales with the size of the input. For example, "O(n)" ("linear time") means the runtime grows proportionally to the size of the input, while "O(n log n)" means it grows slightly faster than linear. Faster algorithms, like O(n), are generally preferred for large datasets. However, it is known that no general sorting algorithms with linear runtime exist.

The comic presents a humorous "linear time" sorting algorithm that first uses merge sort, a well-known O(n log n) algorithm, to sort the list. It then "sleeps" for an additional amount of time to artificially make the runtime scale linearly with the size of the input. Specifically, it pauses for (1 million) * length(list) - (time spent sorting) seconds, which is perhaps large enough (in the case of all practical implementations) to stretch to a knowable point beyond the actual time spent sorting, ensuring the overall runtime appears to grow linearly. This is a joke because the actual sorting is still O(n log n); the additional sleep time is simply wasted time to give the illusion of linear time. It's also a joke because it makes the sort so slow that it's useless, with a "sort" of one item taking upwards of 11 days, two items taking 23 days, three taking 34 days, and so on. Another 'sort' that technically works but takes more time than is necessary,

by definition, is the sleep sort.

The humor lies in the absurdity of intentionally slowing down a sorting algorithm to match a desired runtime profile. This defeats the purpose of optimization, as the goal of sorting algorithms is typically to minimize time spent, not to pad it with unnecessary delays. (Delays may be necessary for other functional reasons, but are an antithesis of the kind of optimality sought here.) If the artificial sleep were removed, the algorithm would revert to its true O(n log n) efficiency, making the "linear sort" label both deceptive and wastefully unnecessary.

The title text extends the joke by referencing "best" and "worst" cases, concepts in algorithm analysis that describe how the runtime varies with different inputs. For the "linear sort," the best and worst cases are identical because the sleep function forces the runtime to always be O(n), regardless of the input. The "worst case for the author," however, is when someone examines the code, exposes the fraud, and damages their reputation—a humorous twist on the idea of worst-case scenarios.

#3027: Exclusion Principle

December 20, 2024

FUNDAMENTAL FORCES

1. GRAVITY
2. ELECTROMAGNETISM
3. THE WEAK INTERACTION
4. THE STRONG INTERACTION
5. ELECTRONS ARE WEIRD ABOUT EACH OTHER

BIG NEWS: PHYSICISTS HAVE FINALLY GIVEN UP TRYING TO EXPLAIN ABOUT THE "EXCHANGE INTERACTION" AND AGREED TO JUST MAKE THE EXCLUSION PRINCIPLE A FORCE.

Fermions are weird about each other in a standoffish way. Integer-spin particles are weird about each other in a 'stand uncomfortably close while talking' kind of way.

Explanation

In this comic, Randall lists the four fundamental forces of physics—gravity, electromagnetism, the weak interaction, and the strong interaction—then humorously adds a fifth force called "Electrons are weird about each other." This is a nod to how electrons cannot occupy exactly the same quantum state. The principle that underlies this is the Pauli exclusion principle (also covered in 658: Orbitals, 1862: Particle Properties, and 2351: Standard Model Changes), which says that no two electrons at the same position (within their de Broglie wavelengths) can have the same set of quantum numbers. The idea behind Pauli exclusion isn't really a conventional "force" like gravity or electromagnetism. Instead, it's a result of the fundamental quantum mechanical rules governing fermions, a class of particles that includes electrons. When combined with electromagnetism, it makes electrons repel each other more than mere electric charge would predict on its own.

This phenomenon is sometimes described via the exchange interaction, which can be tricky to explain to non-experts. Randall's joke is that physicists, frustrated with explaining the subtleties of quantum mechanics, have simply decided to create a "fifth force" to cover the weirdness of electrons. In reality, inventing a fifth force to patch up confusing behavior doesn't improve the accuracy of physicists' predictions of how real-world matter and energy behave; they strive for increasingly accurate descriptions of how nature behaves, rather than

rewriting the rules in ways that compromise their accuracy in predicting physical systems' behavior in favor of simplicity.

In the title text, Randall expands the idea from electrons to all fermions, which have half-integer quantum spin and obey the Pauli exclusion principle, and contrasts them with bosons, which have integer spin and can share the same space. He humorously likens fermions to people standing standoffishly far apart, while bosons are like those who stand uncomfortably close while talking—an imaginative analogy for the fundamental differences in their behaviors.

#3028: D&D Roll

December 23, 2024

I ROLL D20 ... 18.

THE KOBOLD IS UNAFFECTED.

HONESTLY, I DON'T KNOW WHY YOU THOUGHT DICE WOULD HELP. YOU SHOULD PROBABLY TRY A SWORD OR SOMETHING INSTEAD.
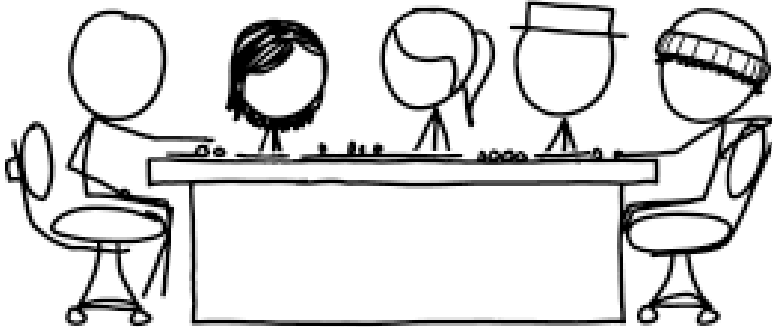
Under some circumstances, if you throw a **D8** and then a **D12** at an enemy, thanks to the **D8**'s greater pointiness you actually have to roll a **D12** and **D8** respectively to determine damage.

Explanation

This comic is a scene from a tabletop roleplaying game, probably Dungeons & Dragons. In 3015: D&D Combinatorics, the same people, Cueball, Megan, Ponytail, White Hat and Knit Cap, are seated playing D&D in the same seats, where Cueball seems to represent Randall.

Here Cueball announces "I roll D20... 18," referring to rolling a 20-sided die and getting the relatively high score of 18, presumably while in a fight with a kobold (a small reptilian humanoid creature in D&D.) The Dungeon Master (DM, or game master), Ponytail, responds that the kobold is unaffected, but suggests using a sword instead, pointing out the absurdity of trying to defeat an enemy by rolling dice at them. (Ponytail was also the dungeon master in the previous D&D comic).

Cueball made the mistake of assuming that Ponytail would understand which of his weapons or other melee attacks he intended to use, but she had no way of knowing that, so she decided to gently tease him about the omission. This is a common mistake, and being gently made fun of is a common result. The player will usually be allowed to state the specific attack intended and roll again.[actual citation needed] It could also have to do with the idea that some people forget D&D is a roleplaying game and just roll dice without explaining, for example, how they charm the shopkeeper.

However, the possibility exists that the players' characters have actual dice, such as those which were role-played as being produced in 244: Tabletop Roleplaying. The title text suggests that if you literally threw dice as weapons, an eight-sided die (D8) would do more damage than a twelve-sided die (D12) because of its pointier shape, so ironically, you might need to roll the D12 to determine the D8's damage and vice versa, in "some circumstances." As per the Background below, those circumstances are considerably slight. The effectiveness of the d65536 in this context has yet to be determined.

Background[edit]

When attacking an enemy in D&D, regardless of the weapon used, the attack starts with a d20 roll to see if it lands a solid hit. If a sufficiently high (or in the earliest editions, sufficiently low) number is rolled, the attack hits, and then further dice (chosen depending on the weapon's form and any magic it might possess) are rolled to determine damage. Before any dice can be rolled at all, however, the player must declare which enemy they are attacking and what with. This is trivial if the attacking character always uses the same weapon and is facing a single enemy, but becomes an important question if the fight is more complex. Consider a case where there are two kobolds present, one wearing plate armor while the other has only a loincloth on (the armor requiring a better d20 roll to defeat), and the player carries both a greatsword (dealing heavy general damage) and the magical "Icepick of Instant Kobold Death" (normally ignored but in this case very useful) and also has magic item that can shoot a destructive Scorching Ray. There are also certain weapons that deal subpar damage on a typical attack, but trigger a powerful

extra effect on a very good roll such as 18, making it even more important to specify which weapon one is using before making the roll. A cheating player might roll first, and then decide which weapon they were using and on which target. This could also be used to avoid wasting a weapon (or particular ammunition) with limited uses.

By D&D 5 rules, a stone hurled from a sling does 1d4 bludgeoning damage. A sling bullet typically weighs 3/40 pound (1.2 oz, 35 g), a plausible weight for a normal-sized die made of a moderately dense material. Presumably, an object of similar weight that's thrown "by hand" rather than with a sling would do less damage, though a heavier object might do similar damage (albeit with less range). The D&D 3.5 spell Magic Stone enhances ordinary small stones so they do 1d6+1 damage when hurled, or 2d6+2 when striking undead creatures. So depending on the setup, a D&D character throwing a die at an enemy could theoretically cause considerable harm, but would normally be much better served with an intentionally crafted weapon.

Alternately, DMs may take umbrage at a player's presumption to roll dice for actions before being asked to, and this could be interpreted as a chiding. Sometimes rolls are not necessary in cases where success is automatic (the kobold is effectively helpless) or impossible (the kobold is magically immune to physical attacks), although it should be the DM's own choice whether to still test for a meaningful critical failure or success, despite it being an apparently foregone conclusion of either kind. There are also other circumstances where the required dice is(/are) different in this instance from that which the player may assume. From a practical perspective, if the performed rolling of the dice is not required (or correctly composed) for the DM's purposes, they can

choose to ignore it and/or ask for some other roll(s) to be made. It may then be the player that might be most upset by having rolled a 'good' roll that has been 'wasted', on the principle that they would have liked it to have it happen later, when it actually mattered, despite this being statistically irrelevant, assuming that the DM doesn't keep any such details mysteriously hidden.

#3029: Sun Avoidance

December 25, 2024

SUN AVOIDANCE SKILL LEADERBOARD

RANK	MISSION	SUN NEAREST MISS
1.		
⋮	[ALL OTHER EXPEDITIONS IN HUMAN HISTORY]	
⋯		
⋮		
1303857.		
1303858.	MARINER-10	69.0 MILLION KM
1303859.	HELIOS 1	46.4 MILLION KM
1303860.	BEPICOLOMBO	45.8 MILLION KM
1303861.	MESSENGER	45.3 MILLION KM
1303862.	SOLAR ORBITER	43.8 MILLION KM
1303863.	HELIOS 2	43.3 MILLION KM
1303864.	PARKER	6.17 MILLION KM

CONGRATULATIONS TO THE PARKER SOLAR PROBE FOR SETTING A NEW RECORD FOR "WORST JOB AVOIDING THE SUN."

C'mon, ESA Solar Orbiter team, just give the Parker probe a LITTLE nudge at aphelion. Crash it into the sun. Fulfill the dream of Icarus. It is your destiny.

Explanation

The comic humorously ranks space missions based on their ability to "avoid" the Sun, presenting it as a "Sun Avoidance Skill Leaderboard." Most space missions remain relatively far from the Sun, with distances in the tens of millions of kilometers. However, the Parker Solar Probe is listed at the bottom of the leaderboard because it has come significantly closer to the Sun than any other spacecraft, at just 6.17 million kilometers. The joke lies in framing this incredible scientific achievement as a "failure" in avoiding the Sun.

The missions listed include notable solar and planetary exploration spacecraft like Mariner 10, Helios 1, BepiColombo, MESSENGER, and Solar Orbiter. These missions, designed to study the Sun or its surroundings, are ranked by their closest approaches to the Sun. The comic highlights the vast difference between the Parker Solar Probe and all other missions, emphasizing its unprecedented proximity to the Sun as part of its mission to study the solar corona and solar wind.

The inclusion of "All Other Expeditions in Human History" at the top of the leaderboard adds to the humor by lumping together all non-Sun-focused missions, which obviously maintain much greater distances from the Sun. The comic concludes with a sarcastic congratulation to the Parker Solar Probe for its "worst job avoiding the Sun," humorously subverting the intention and achievement of the mission.

The caption text further expands on the joke by mockingly framing the Parker Solar Probe's proximity to the Sun as a skill-based failure. It suggests that its operators have demonstrated the "worst Sun avoidance skill" ever. This playful jab contrasts with the reality that the Parker Solar Probe's engineers and scientists intentionally designed the spacecraft to approach the Sun closer than ever before, enduring extreme heat and radiation to gather groundbreaking scientific data.

The title text references the Greek legend of Icarus, whose father crafted artificial wings so the two of them could fly out of the open-topped prison they were in. Icarus, despite his father's warnings, flew too high which, according to the myth, got him appreciably closer to the Sun where it was much hotter, hot enough to destroy Icarus's wings, which caused him to plummet from a very high altitude to his death. The comic reframes this from an unfortunate consequence of his overreaching, to a glorious failure of an attempt to destroy himself by reaching the Sun itself. (As humanity has learned since then, the upper reaches of Earth's atmosphere are cold, not hot, and the distance from Earth's surface to the upper reaches of its atmosphere is only a tiny fraction of the total distance from the Earth to the Sun.) The caption text urges the operators of another satellite to use their satellite to alter the Parker Solar Probe's orbit to send it into the Sun, which would by definition lower the Parker Solar Probe's distance from the Sun to zero. Unfortunately, the Parker Solar Probe was only designed to get close to the Sun, not into it, and would be

destroyed soon after entering the Sun if not before. Being destroyed would prevent the Parker Solar Probe from transmitting any further data, terminating its mission. Its operators would probably object to this.[citation needed]

#3030: Lasering Incidents

December 27, 2024

SOMEONE IS COMMITTING A FEDERAL CRIME RIGHT HERE →

I DON'T KNOW WHY PEOPLE WHO SHINE LASERS AT AIRCRAFT ARE SURPRISED WHEN THE POLICE CATCH THEM, GIVEN THAT THE CRIME CONSISTS OF DRAWING A GIANT GLOWING ARROW IN THE SKY POINTING AT YOUR LOCATION.

I still don't know how the police found my compound where I ran an illegal searchlight depot/covert blimp airfield/fireworks testing range.

Explanation

This comic is about pointing lasers at aircraft, which is a federal crime in the USA because the powerful laser light could temporarily distract or blind the pilot, or cause burns and eye injuries if the laser is powerful enough. (This had been previously mentioned in 2481: 1991 and 2021.) It points out that when a laser is pointed at an aircraft, the pilot or anyone else on board can see a glowing line in the color of the laser exactly pinpointing the location of the perpetrator. While the length of the beam itself is invisible in perfectly clear conditions, any particles in the air along their length will be highlighted by the beam, effectively forming a visible line stretching from the laser point to the aircraft. This is especially true in dark conditions, since any reflecting particles will be particularly obvious in such a case. This is related to the old military adage "tracers work both ways", meaning that tracer ammunition reveals the origin point of the bullet just as effectively as it reveals its destination.

Given this, it can be relatively trivial for authorities to identify where the laser beams are coming from, and quickly apprehend anyone committing these crimes. Randall suggests that some people shine lasers at aircraft seem surprised when they're caught, but points out that such a consequence is nearly inevitable. This comic might be a response to the 2024 United States drone sightings, during which many people in New Jersey collectively forgot what a plane is and started pointing laser pointers at them.

The title text parodies this kind of crime by describing a criminal activity which also makes itself particularly obvious, namely illegal fireworks testing, blimp airfield and searchlight depot, the conspicuous activities of all being clearly visible across a wide area. Such depots, airfields and ranges aren't intrinsically illegal in the US, but typically will need some form of official registration; Randall's examples clearly do not obey the appropriate FAA regulations, zoning laws, etc.

#3031: Time Capsule Instructions

December 30, 2024
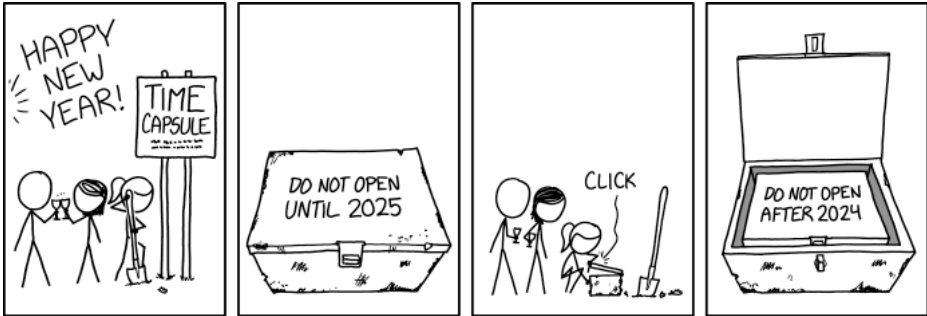
Inside is a third box, labeled DO NOT OPEN UNLESS YOU ARE IN THE TIME ZONE WHERE YOU OPENED BOTH PREVIOUS BOXES.

Explanation

This New Year comic sees a New Year party held at a location where a time capsule has clearly been buried, as evidenced by a sign marking the spot. It is likely that this was buried some years ago with the intention of being unearthed at the start of 2025, after some significant number of years have passed, rather than for an indeterminate amount of time (such as was the case in 1617: Time Capsule), with the intent to allow people of a then-future time see what those of that era found interesting to preserve and "send" into the future.

Some form of New Year Celebration is happening near to the Time Capsule site, as indicated by the off-panel noises, probably especially convened at the capsule's site in eager anticipation. Cueball and Megan, who have already said cheers with their wine glasses, look eagerly on when Ponytail opens the time capsule.

Not all such projects are kept conspicuously marked, or may lose their signage due to circumstances unanticipated at the time of the original installation, resulting in a surprise (or accidental) unearthing, while others may still be known for what they are (as with the intended time to stay closed) but need to be relocated/reconcealed due to later redevelopment of the location. (There is generally nothing to prevent premature unearthing and opening, perhaps especially to ensure that the contents are not damaged, but often efforts are taken to best adhere to the original wishes.) To

this end, as might be expected of such a time capsule, the box that Ponytail digs out is itself marked that it must not be opened until the year 2025 and it seems that (for the comic) this is the case, and at least part of the reason for the gathering.

Within the capsule, however, is a second container (a not atypical precaution), but this one has the instruction to not open after 2024, which is a far less obvious element for a time capsule (though various supplies, from packaged food to signal flares, may have a similar requirement). Obeying the instruction for opening the first box has entirely precluded obeying that given as a prerequisite for opening the second… at least without using some form of time-travel. This could be either be a mundane twist of the circumstances (changing reference calendars or time-zones), or else require actual time-travel, but it is unlikely that they have any practical solution prepared to use to overcome this twist.

The title text makes the situation more similar to Matryoshka dolls, where boxes are recursively stacked, with a third label having another restriction. This new label alludes to one of the ways one can open the first two boxes without ignoring the instructions: by crossing time zones. When more easterly-referenced locations have become the 1st of January 2025, it will (for a short while) still be the 31st of December 2024 in more westerly ones (the boundaries themselves might be any orientation, not just north-south; the whole concept inverts across the International Date Line, before even considering hour-shift differences), meaning that

theoretically someone could open the first box in a time zone where it is 2025 and then quickly travel to one in which it is still 2024 to open the second box. Depending upon where the capsule was located, timely travel opportunities may be possible, but it seems unlikely to have been something anticipated by the recipients of the task.

However, the title text implies that if you take advantage of this loophole, you will not then be allowed to open a third box inside the second box, as the instructions for that box requires that you have opened the first two boxes in the same time zone. You must not open the third (and final?) container unless you opened both previous boxes in the same time zone as you are now, which is not compatible with having changed location to get to this point.

Potential solutions[edit]

Depending on interpretation, you could defeat the third box by placing it inside two time zones at once before opening it, as there is no time limit on the third box. This works if the instruction on the box is read as "unless you are in the time zone where you opened the first box, and you are in the time zone where you opened the second box". However, this new loophole could be patched by interpreting the third box as "unless you are in the one time zone where…".

How to be considered to be simultaneously covered by two time-zones (in a way that you can choose which to observe) is left up to the reader, although another variation of this solution

would be to change the calendar used as point of reference, as many calendars use a lower year than the Gregorian calendar, or is offset by a few days, and you could justify changing the date (if not the hour) that you consider true. Or perhaps mix and match calendar traditions that consider a day (and therefore a calendar date) to start only at dawn, rather than at astronomical/geopolitical midnight.

Perhaps the solution would be for both the box and the person opening it to be on the boundary between two time zones, half in each. Or, depending on how one interprets the nature of Daylight Saving Time, there may be another solution. In Australia, Northern Territory and South Australia are in the same time zone (by the most common interpretation of the word) and border each other, but only the latter uses Daylight Saving Time; similarly, Queensland does not use Daylight Saving Time but is in the same time zone (by the most common interpretation of the word) as multiple Australian territories that do use Daylight Saving Time, including New South Wales, with which Queensland shares a border. This suggests the idea of opening the first box in South Australia or New South Wales then taking it north of the (latitudinal) DST boundary without crossing any (longitudinal) time zone boundaries; one will then have up to an hour to open the second box and then as long as one wants to open the third box. However, Randall has historically expressed opposition to Daylight Saving Time, so he might not count the first opening as occurring in 2025 if that year has already started only by virtue of Daylight Saving Time.

Without any tricksy thinking and assuming we may not have the box nor the person opening the box in two time zones at the same time, a semantic loophole presents itself. The title text refers to

"you" and not the box, while the instructions on the first and seconds boxes can be reasonably assumed to apply only to the time zone that the box itself is in. The box could be moved from one time zone to the other by the use of, as an example, a robotic arm, then opened, and then brought to the time zone that the person controlling the robotic arms is in. Alternatively, if two different people opened the first two boxes in the respective time zones, the "you" would then have to be reconsidered as plural, and, since both people could stay in their respective time zones, the third box could be opened.

Some of the above solutions might only be used if you already knew of the instructions on the boxes, unless it was previously dug into one of the relevant locations (and, depending upon the 'author' of the box-puzzle, this may have also been anticipated and be an intended part of the puzzle). Even getting the second box open following instructions would require it was possible to travel fast enough and far enough to reach a second New Year, which is not easily guaranteeable on the spur of the moment. This is definitely possible if you plan for it, but whether this disinterment party was prepared is unlikely.

Having made the initial two openings in different locations, another possibility is to choose either location (it being easiest to remain where you were allowed to open the second box) and having removed all boxes from any prior host containers, close the box that is now out-of-zone. You can now either take the box's mandate as dealt with, and expired, or avoid any quibbles by waiting just long enough for the now-closed 2025 box to once more experience 2025 in the second box's locale, permitting you to re-open it and fulfil the requirements of the third.

In any case it seems more likely that normal people, having taken the initial instruction at its word, would ignore any new contradictory rules. The original rule that the Time Capsule should remain closed until 2025 is the one that makes sense. So after opening the first at the right time, one could just disregard the words on the boxes (or at least Randall's interpretation of them); there is probably not some kind of magical enforcement mechanism. Also it seems likely this was just a prank so there will be nothing interesting inside, but one might fear some kind of booby trap, or a bobcat. So there could be some kind of enforcement mechanism.

Considering when the comic was published, however, a full day prior to any territory having actually celebrated the arrival of 2025, one might imagine that this is not an upcoming scenario, but one that has happened/is happening already. In this case, it suggests that the party (both diggers-up and associated party-goers) were fully aware of some of the stipulations they were to be subject to and (impatiently, or at even just as cleverly as the initial burier of the boxes) arbitrarily marked the arrival of 2025 early to 'justify' the opening the outer box. They could then conveniently reconsider their schedule, continuing now on the basis of acting prior to the end of 2024, and have no further trouble with either of the inner instructions (opening the next box before the official arrival of 2025 would be simplicity, and any antecedent calendar reinterpretations could be considered logically separated from any prohibitive change in location and/or time-zone).

There is also the question of a hypothetical fourth box, which, given that there was a third box, there is no reason that there shouldn't be a fourth, probably with a label designed to better

shut down some of these potential solutions. And maybe it's boxes all the way down!

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